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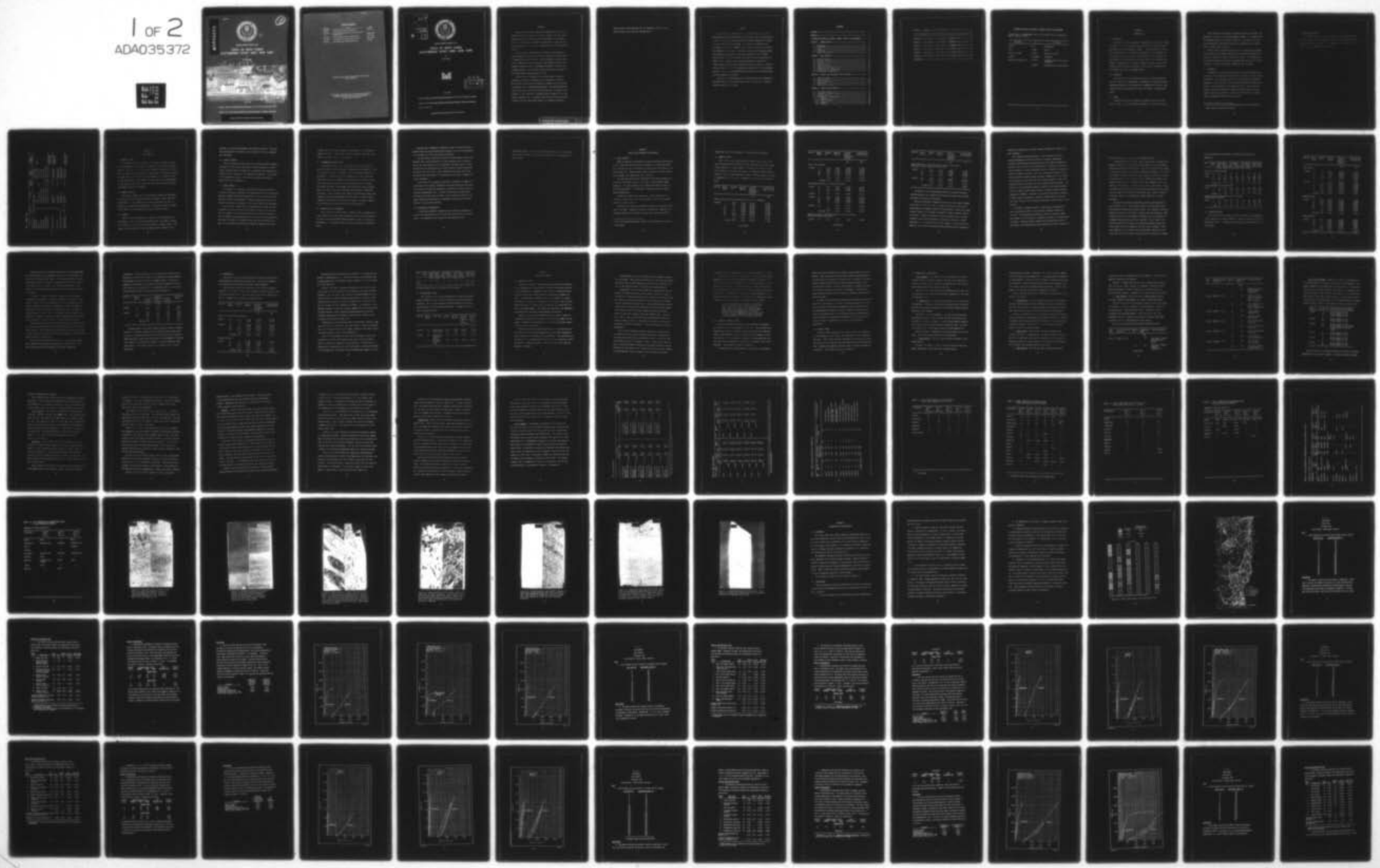

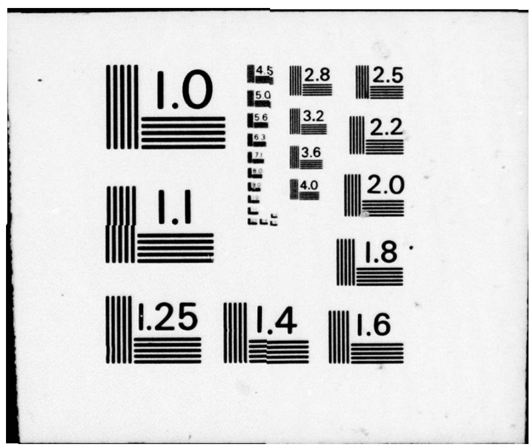
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MISCELLANEOUS PAPER C-70-7

TESTS OF ROCK CORES PLATTSBURGH STUDY AREA, NEW YORK

by

R. W. Crisp

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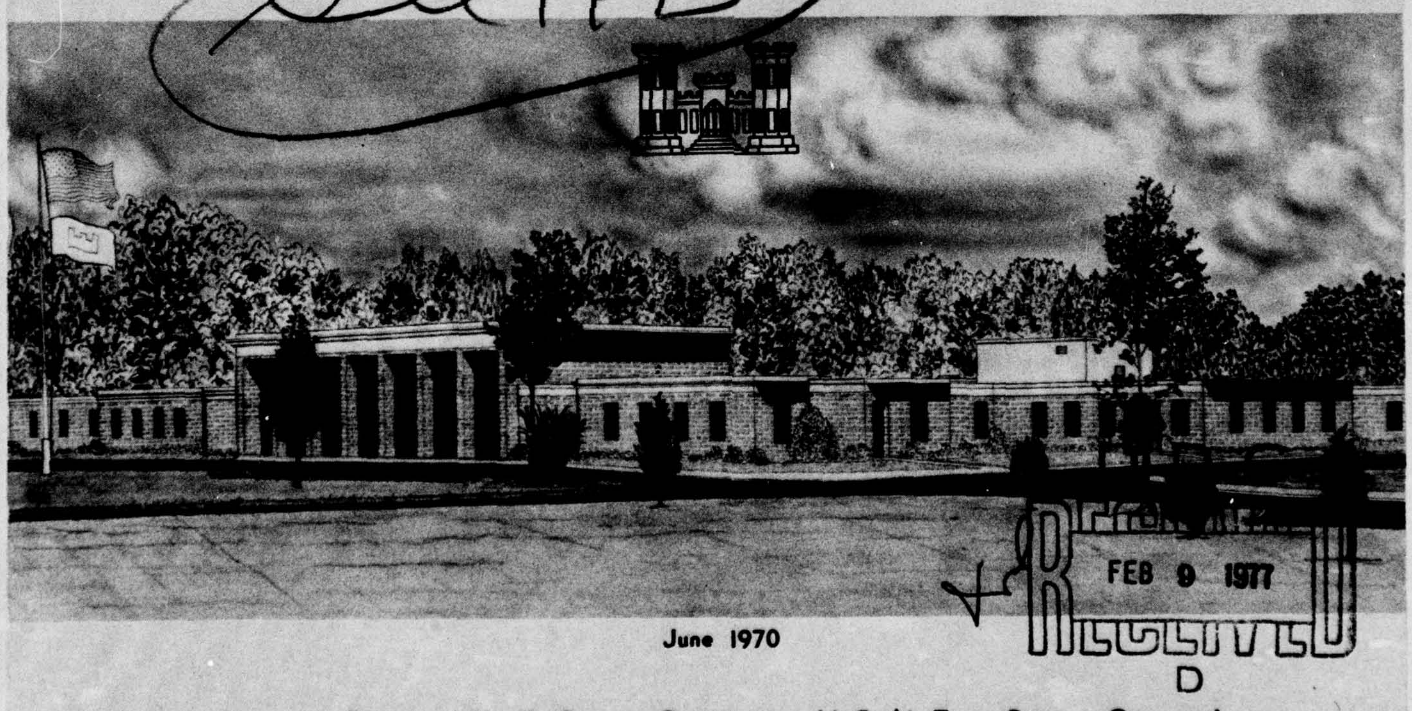

June 1970

Sponsored by Space and Missile Systems Organization, U. S. Air Force Systems Command

Conducted by U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi

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ASSOCIATED REPORTS

Report No.	Title	Date
MP C-69-3	*Tests of Rock Cores*, Warren Area, Wyoming	March 1969
MP C-69-12	*Tests of Rock Cores*, Mountain Home, Idaho, and Fairchild, Washington, Areas	September 1969
MP C-69-16	Tests of Rock Cores, Castle Study Area, California	October 1969
MP C-70-4	Tests of Rock Cores, Bergstrom Study Area, Texas	February 1970
MP C-70-6	*Tests of Rock Cores*, Scott Study Area, Missouri	May 1970

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ARMY-MRC VICKSBURG, MISS.

ABSTRACT

Laboratory tests were conducted on representative rock core specimens received from six core holes located in Clinton, Essex, Franklin, and Warren Counties near Plattsburgh Air Force Base, New York. The results of these tests were used to gage the quality and uniformity of the rock to depths of 200 feet below ground surface.

The core was petrographically identified as predominately quartz sandstone and granite gneiss with relatively small amounts of amphibolite and mica schist. Schmidt hardness, specific gravities, compressional wave velocities, and ultimate uniaxial compressive strengths varied considerably throughout the area, depending primarily on rock type, bedding, and nature and degree of fracturing and/or banding present, if any.

A hole-to-hole evaluation of the area, based on physical properties exhibited, indicates that the sandstone yielded by Holes P-CR-64 and P-CR-72 was generally competent rock, provided anisotropy is not a disqualifying quality. The granite gneisses tested from Holes P-CR-22 and P-CR-81 would also, in spite of the presence of some material of marginal quality, appear to be relatively competent rock. The gneiss received from Holes P-CR-8 and P-CR-46 contained significant amounts of incompetent material.

More extensive investigations will be required in order to accurately assess the areas under consideration.

PREFACE

This study was conducted in the Concrete Division of the U. S. Army Engineer Waterways Experiment Station (WES) under the sponsorship of the U. S. Air Force Space and Missile Systems Organization (SAMSO) of the Air Force Systems Command. The study was coordinated with CPT Rupert G. Tart, Jr., SAMSO Project Officer, Norton Air Force Base, San Bernardino, California. The work was accomplished during October and November of 1969 under the general supervision of Mr. Bryant Mather, Chief, Concrete Division, and under the direct supervision of Messrs. J. M. Polatty, Chief, Engineering Mechanics Branch, W. O. Tynes, Chief, Concrete and Rock Properties Section, and K. L. Saucier, Project Officer. Mr. C. R. Hallford was responsible for the petrography work. Mr. R. W. Crisp performed the majority of the program analysis and prepared this report.

Director of the WES during the investigation and the preparation and publication of this report was COL Levi A. Brown, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows.

Multiply	By	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
feet per second	0.3048	meters per second
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms (force) per square centimeter
	6.894757	kilonewtons per square meter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The purpose of this study was to supplement the information being obtained for the area evaluation study by the U. S. Air Force Space and Missile Systems Organization (SAMSO). It was necessary to determine the properties of the specific materials for (1) evaluation of the area as a hard rock medium, (2) utilization in the various computer codes for ground-motion predictions, and (3) as necessary, for design of structures in the medium. Results of tests on cores from Clinton, Essex, Franklin, and Warren Counties near Plattsburgh Air Force Base, New York, are reported herein.

1.2 OBJECTIVE

The objective of this investigation was to conduct laboratory tests on samples from study areas to determine the integrity and the mechanical behavior of the materials as completely as possible, analyze the data thus obtained, and report the results to appropriate users.

1.3 SCOPE

Laboratory tests were conducted on samples received from the field. Table 1.1 gives pertinent information on the various tests.

Tests conducted to determine the general quality, uniformity, and integrity of the rock in the area sampled included: (1) relative hardness (Schmidt number), (2) specific gravity, (3) porosity, (4) unconfined compression (conventional and cyclic compression), (5) elastic moduli, and (6) sonic velocity.

Special tests conducted respectively (1) to determine the degree of anisotropy of the sampled rock and (2) to facilitate comparison of results of direct and indirect tensile tests were: (1) dynamic elastic properties along three mutually perpendicular axes and (2) tensile strength. A limited petrographic examination was also made.

1.4 SPECIMENS

Specimens were received from six holes in the Plattsburgh area. These holes were designated P-CR-8, P-CR-22, P-CR-46, P-CR-64, P-CR-72, and P-CR-81. All specimens were NX size cores (nominal 2-1/8-inch[1] diameter). Test specimens of the required dimensions as presented in Table 1.1 were prepared for the individual tests. Quality and uniformity tests were conducted on selected specimens from all holes. Special tests were conducted on specimens selected from the various holes to represent differences in rock type.

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[1] A table of factors for converting British units of measurement to metric units is presented on page 8.

1.5 REPORT REQUIREMENTS

The immediate need for the test results required that data reports be compiled and forwarded to the users as work was completed on each hole. The data reports of the individual test results are included herein as Appendixes A through F.

TABLE 1.1 SUMMARY OF TESTS

Test	Specimen Size	Test Equipment	Recording Equipment	Measured Properties	Computed Properties
Relative hardness	1 diam by 2 diam	Schmidt hammer	--	Relative hardness	--
Specific gravity		Scales	--	Specific gravity	Density
Porosity		Pressure pycnometer	Scales	Porosity, percent	--
Indirect tension		440,000-pound test machine	--	Tensile strength	--
Direct tension		30,000-pound test machine	--	Tensile strength	--
Unconfined compression		440,000-pound test machine	X-Y recorder	Compressive strength	--
Cyclic compression		440,000-pound test machine	X-Y recorder	Compressive strength	Young's, shear, and bulk moduli and Poisson's ratio
Dynamic elastic moduli		Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	Young's, shear, and bulk moduli and Poisson's ratio
Sonic velocity		Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	--
Petrographic examination	Variable	Microscopes, X-ray diffraction	--	Appearance, texture, and mineralogy	--
Three-directional dynamic elastic properties	1 diam by 1 diam	Pulse generator, amplifiers	Oscilloscope	Compressional and shear velocities	Young's, shear, and bulk moduli and Poisson's ratio

CHAPTER 2

TEST METHODS

2.1 SCHMIDT NUMBER

The Schmidt number is a measure of the relative degree of hardness as determined by the degree of rebound of a small mass propelled against a test surface. The test was conducted as suggested in Reference 1 (a Swiss-made hammer was used) except that 12 readings per specimen were made. The average of these readings is the Schmidt number or relative hardness. The hardness is often taken as an approximation of rock quality, and may be correlated with other physical tests such as strength, density, and modulus.

2.2 SPECIFIC GRAVITY

The specific gravity of the "as-received" samples was determined by the loss of weight method conducted according to Method CRD-C 107 of Reference 2. A pycnometer is utilized to determine the loss of weight of the sample upon submergence. The specific gravity is equal to the weight in air divided by the loss of weight in water.

2.3 POROSITY

Porosity, herein defined as the volume of voids expressed as a percentage of total volume, was determined after the samples utilized for the specific gravity test had been dried to constant weight. The amount of water forced into the test sample under 1,200-psi fluid

pressure in a pressure pycnometer was carefully measured. Utilizing the known density of the water, the void space in the test specimen was calculated.

2.4 INDIRECT TENSION

Tensile strength was determined by the indirect method, commonly referred to as the tensile splitting or Brazilian method, in which a tensile failure stress is induced in a cylindrical test specimen by a compressive force applied on two diametrically opposite line elements of the cylindrical surface. The test was conducted according to Method CRD-C 77 of Reference 2.

2.5 DIRECT TENSION

For purposes of comparison, specimens were prepared and tested for tensile strength according to the American Society for Testing and Materials (ASTM) proposed "Standard Method of Test for Direct Tensile Strength of Rock Core Specimens." Tensile splitting tests were conducted on specimens cut adjacent to the direct tensile test specimens.

For the direct tension tests, the specimens were right circular cylinders, the sides of which were straight to within 0.01 inch over the full length of the specimen and the ends of which were parallel and not departing from perpendicularity to the axis of the specimen by more than 0.25 degree. Cylindrical metal caps were cemented to the ends of the specimen and provided the means for applying the direct

tensile load. The load was applied continuously by a 30,000-pound-capacity universal testing machine and at a constant rate such that failure occurred within 5 to 15 minutes.

2.6 COMPRESSIVE STRENGTH TESTS

The unconfined and cyclic compression test specimens were prepared according to ASTM and Corps of Engineers standard method of test for triaxial strength of undrained rock core specimens (CRD-C 147, Reference 2). Essentially, the specimens were cut with a diamond blade saw, and the cut surfaces were ground to a tolerance of 0.001 inch across any diameter with a surface grinder prior to testing. Electrical resistance strain gages were utilized for strain measurements, two each in the axial (vertical) and horizontal (diametral) directions. Static Young's, bulk, shear, and constrained moduli were computed from strain measurements and were based on tangent moduli computed at 50 percent of the ultimate strength. Stress was applied with a 440,000-pound-capacity universal testing machine.

2.7 DYNAMIC ELASTIC PROPERTIES

Bulk, shear, and Young's moduli, Poisson's ratio, compressive velocity, and shear velocity were determined on selected rock specimens by use of the proposed ASTM "Standard Method of Test for Laboratory Determination of Ultrasonic Pulse Velocities and Elastic Constants of Rock."

Specimens were prepared by cutting the ends of the NX core with a diamond blade saw, and grinding these surfaces, with a surface grinder, to a tolerance of 0.001 inch across any diameter.

The test method essentially consisted of generating a wave in the specimen with a pulse generator unit and measuring, with an oscilloscope, the time required for the compression and shear waves to travel the specimen, the resulting wave velocity being the distance traveled divided by the travel time. These compressive and shear velocities, along with the bulk density of the specimen, were used to compute the elastic properties.

In the case of the special tests used to determine the degree of anisotropy of the samples, compression and shear velocities were measured along two mutually perpendicular, diametrical (lateral) axes and along the longitudinal axis. This was facilitated by grinding four 1/2-inch-wide strips down the sides of the cylindrical surface at 90-degree angles and generating the compressive and shear waves perpendicular to these ground surfaces.

2.8 PETROGRAPHIC EXAMINATION

A limited petrographic examination was conducted on samples selected to be representative of the material received from the several holes. The examination was limited to identifying the rock,

determining general condition, identifying mineralogical constituents, and noting any unusual characteristics which may have influenced the test results.

CHAPTER 3

QUALITY AND UNIFORMITY TEST RESULTS

3.1 TESTS UTILIZED

Based on experience accumulated through testing and data analysis of core from study areas previously evaluated,[1] the following tests were selected for use in determining the quality and uniformity of the Plattsburgh core: Schmidt number, specific gravity, uniaxial compressive strength, and compressional wave velocity.

The core received from the Plattsburgh study area generally consisted of three types of rock: (1) Fine- to coarse-grained quartz sandstone. (2) Poorly banded to well banded and poorly foliated to well foliated gneiss. (3) Dark-gray to dark-gray-and-red, medium-grained amphibolite.

Relatively insignificant quantities of other materials--two specimens of mica schist, one of black basalt, and one of disrupted quartz--were also received.

Physical test results were generally grouped and analyzed according to rock type. Frequently, however, the data also suggested and reflected subdivision according to grain size, nature and degree of

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[1] A list of associated reports is given on the inside front cover of this report.

fracturing, and nature and degree of foliation and/or banding.

3.2 GRANITE GNEISS

All of the core received from Hole P-CR-46, as well as most of that received from Holes P-CR-8, P-CR-22, and P-CR-81, was petrographically identified as granite gneiss. Physical test results showed good correlation with nature and degree of fracturing and/or banding present in the individual specimens tested. Detailed results are given in Appendixes A, B, C, and F. A summary of the results is presented below.

Hole No.	Specimen No.	Schmidt No.	Specific Gravity	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Intact or with Well Healed Fractures, Little or No Banding:					
P-CR-81	3	58.1	2.734	27,300	17,685
	7	51.3	2.729	26,360	16,985
	11	--	2.684	30,610	14,290
	14	--	2.694	20,760	16,190
	15	45.2	2.959	27,970	16,840
	17	--	2.768	22,090	19,440
	19	42.7	3.076	21,420	20,490
	21	44.9	2.864	24,360	19,700
	Average	48.4	2.814	25,110	17,700

(Continued)

Hole No.	Specimen No.	Schmidt No.	Specific Gravity	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Intact, Well Banded:					
P-CR-22	2	45.2	2.994	15,000	15,480
	5	43.0	2.713	14,640	11,390
	16	48.6	2.703	19,330	12,145
	20	43.4	2.737	21,545	13,125
	22	44.2	2.706	21,330	13,710
	Average	44.9	2.771	18,370	13,170
Containing Horizontal or Vertical Fractures:					
P-CR-8	8	42.6	2.741	14,790	14,770
	11	--	3.051	14,330	16,610
	12	40.1	2.776	13,580	15,095
P-CR-22	4	46.4	2.746	13,880	16,510
P-CR-46	8	45.8	2.793	14,605	15,620
	15	49.8	2.686	8,605	14,740
	19	--	2.704	16,180	15,575
	21	--	2.691	13,970	14,935
P-CR-81	10	--	2.634	20,760	13,900
	Average	44.9	2.758	14,520	15,310
Highly Fractured, Containing Sealed Joints or Containing Critically Oriented Fractures:					
P-CR-8	17	39.5	3.018	3,450	16,075

(Continued)

Hole No.	Specimen No.	Schmidt No.	Specific Gravity	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Highly Fractured, Containing Sealed Joints or Containing Critically Oriented Fractures (Continued):					
P-CR-46	7	48.5	2.667	4,985	15,110
	10	48.4	2.708	4,790	15,225
	17	--	2.691	8,545	13,780
	18	40.6	2.678	8,575	14,550
P-CR-81	18	44.9	2.746	9,520	16,150
	20	42.8	2.919	8,760	20,300
	Average	44.1	2.775	6,950	15,880

The gneiss from the Plattsburgh study area exhibited somewhat variable physical test results which depended primarily upon banding and nature and degree of fracturing.

Uniaxial compressive strengths exhibited by this material ranged from 3,000 to 30,000 psi, with the intact (according to Reference 1, macroscopically homogeneous and free from fractures, joints, and seams) slightly banded core yielding the greatest ultimate strengths and the critically to highly fractured core (rock containing open or sealed fractures, well developed systems of fracture, critically oriented fractures, i.e., fractures inclined with respect to the horizontal at angles so as to develop failing shearing stresses when the specimen is

subjected to relatively low axial stresses) yielding the lowest ultimate strengths.

The incipient fractures present in some specimens were well healed and apparently had little effect on uniaxial compressive strength; these specimens exhibited some of the highest strengths observed in the core from the Plattsburgh area. Relatively well developed horizontal or vertical fractures, however, appeared to cause substantial strength reductions. The core containing fractures of this nature exhibited average ultimate strengths ranging from 50 to 75 percent as great as those exhibited by the intact material or that containing incipient fractures (both well banded and poorly banded). The presence of well developed systems of fracture, critically oriented fractures, and/or sealed joints resulted in greatly reduced ultimate compressive strengths. Material of this nature exhibited an average ultimate uniaxial compressive strength of approximately 7,000 psi, less than 30 percent of the average exhibited by poorly banded, intact material.

The degree of banding present in the gneiss also appeared to have a substantial effect on the ultimate strengths exhibited by the core. This banding was generally inclined at moderate angles with respect to the horizontal, frequently resulting in failure along the bands. Ultimate uniaxial compressive strengths exhibited by the intact, well banded gneiss were generally less than 75 percent of

those exhibited by the intact, poorly banded material.

Compressional wave velocities varied considerably throughout the group, showing only a slight trend toward higher values in specimens exhibiting higher ultimate strengths. One of the factors which seemed to contribute strongly to the large variation was banding. The intact, well banded material yielded the lowest average velocity in the granite gneiss group, while the intact, poorly banded core exhibited the highest average velocity. Another factor which apparently had some effect was the presence of garnet in some cores. These small, irregular masses could possibly have deflected the compressional wave resulting in a longer than normal path and travel time. Garnet concentrations also resulted in substantially higher densities of several specimens.

The gneisses exhibited noticeable hysteresis when subjected to static elastic tests. Upon cycling, however, several gneiss specimens exhibited substantial residual strain. This residual strain was generally detected in critically to highly fractured specimens, indicating possibly that the permanent deformation was due primarily to slippage along preexisting fracture surfaces. Static elastic constants exhibited by the gneiss were generally somewhat larger than those exhibited by the sandstone, but were rather variable. There also appeared to be a general trend toward higher moduli (both dynamic and static) with higher ultimate uniaxial compressive strength,

as is illustrated by the elastic constants in the following tabulation.

Hole No.	Specimen No.	Young's Modulus		Bulk Modulus		Shear Modulus		Poisson's Ratio	
		Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic
		10^6 psi	10^6 psi	10^6 psi	10^6 psi	10^6 psi	10^6 psi		
Intact or with Incipient Fractures:									
P-CR-22	20	8.0	5.5	3.9	5.4	3.5	2.2	0.16	0.23
P-CR-81	3	8.5	8.8	5.7	6.9	3.4	3.4	0.25	0.29
	15	12.2	9.6	8.4	6.1	4.8	3.9	0.26	0.24
	21	9.1	10.2	5.7	9.8	3.7	3.8	0.24	0.33
	Average	9.4	8.5	5.9	7.0	3.8	3.3	0.23	0.27
Containing Horizontal or Vertical Fractures:									
P-CR-8	8	6.7	7.1	3.3	4.2	2.9	2.9	0.16	0.22
	11	7.8	10.5	4.5	5.3	3.2	4.5	0.21	0.17
	Average	7.2	8.8	3.9	4.8	3.0	3.7	0.18	0.20
Highly Fractured, Containing Sealed Joints, or Containing Critically Oriented Fractures:									
P-CR-46	7	3.3	6.8	1.9	4.6	1.6	2.7	0.03	0.25
	17	6.2	6.5	3.1	3.1	2.7	2.8	0.16	0.15
	Average	4.8	6.6	2.5	3.8	2.2	2.8	0.10	0.20

3.3 QUARTZ SANDSTONE

The core received from Holes P-CR-64 and P-CR-72 was petrographically identified as quartz sandstone. Detailed results are given in Appendixes D and E. A summary of the results is presented on the following page.

Hole No.	Specimen No.	Schmidt No.	Specific Gravity	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Fine Grained:					
P-CR-64	2	47.4	2.645	31,670	9,765
	4	--	2.633	21,760	11,810
	6	--	2.697	30,450	14,010
	8	45.9	2.622	30,910	11,305
	10	50.6	2.631	25,300	12,255
P-CR-72	1	--	2.631	24,700	8,010
	2	45.7	2.596	30,000	9,190
	4	49.9	2.550	34,700	9,190
	6	54.0	2.510	22,050	12,060
	18	--	2.545	15,210	8,620
	Average	48.9	2.606	26,680	10,620
Medium Grained:					
P-CR-72	9	49.5	2.585	25,610	13,030
	10	47.8	2.525	15,920	9,180
	12	48.8	2.494	13,830	8,530
	14	47.5	2.587	19,700	10,230
	17	--	2.613	17,000	9,790
	20	--	2.519	13,030	7,570
	Average	48.4	2.554	17,520	9,720
Coarse Grained:					
P-CR-64	14	50.7	2.592	17,420	10,985
	16	--	2.600	18,940	10,615
	18	--	2.585	17,080	10,535
	21	--	2.573	12,210	8,655
	27	44.3	2.532	15,520	9,655
	Average	47.5	2.576	16,230	10,090

Uniaxial compressive strengths exhibited by the sandstones from this area appeared to be dependent upon grain size, particularly in the fine- to medium-grained range. The fine-grained material exhibited average uniaxial compressive strengths nearly twice as large as those exhibited by the medium- and coarse-grained material. The medium- and coarse-grained specimens exhibited very similar physical test results.

A search of available literature revealed little information concerning the dependence of uniaxial compressive strength for sandstones on grain size, but did indicate that such strengths were frequently dependent upon porosity, permeability, nature and degree of cementation, surface texture of the sand grains, and the nature of bedding present, if any. Thus, it is possible that the apparent dependence of strength on grain size might actually have been a dependence on variation in one or more of the above-mentioned factors.

Compressional wave velocities were generally low, somewhat higher for the fine-grained material. Rather large variations were observed within groups. These variations are probably due again to differences in matrix material, porosity, nature and orientation of bedding planes, and/or variation in grain size.

Like the gneiss discussed in Section 3.2, the sandstones exhibited considerable hysteresis when subjected to static tests. But, upon cycling, axial strain appeared to be almost completely

recoverable. Initial curvature of the stress-strain curves was possibly due to initial void closure in this moderately porous material. Static elastic constants based on a tangent modulus of elasticity computed at 50 percent of the ultimate uniaxial compressive strength were rather low, as indicated in the tabulation below, but were very uniform and well within the range noted in Reference 3.

Hole No.	Specimen No.	Modulus			Poisson's Ratio
		Young's	Bulk	Shear	
		10^6 psi	10^6 psi	10^6 psi	
P-CR-64	4	6.7	2.8	3.0	0.10
	27	5.0	1.9	2.2	0.12
P-CR-72	2	5.9	2.3	2.8	0.07
	4	6.8	3.0	3.0	0.12
	14	5.1	2.2	2.8	0.12
	Average	5.9	2.4	2.8	0.11

Although dynamic tests were conducted, dynamic elastic constants could not be reliably computed from the unrealistically large shear velocity to compressional velocity ratios exhibited by this material. These unrealistic ratios were quite possibly a consequence of attempting to apply a test whose basic premise is that the material under observation is very nearly isotropic to a material that is highly anisotropic.

3.4 AMPHIBOLITE

Portions of the core received from Holes P-CR-8 and P-CR-22 were petrographically identified as amphibolite. Several of the amphibolite specimens were fractured; some were severely sheared.

Physical test results were indicative of two distinct groups of material: (1) intact core and core containing vertical fractures, and (2) highly fractured core. Detailed results are given in Appendixes A and B. A summary of the results is presented below.

Hole No.	Specimen No.	Schmidt No.	Specific Gravity	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
				psi	fps
Intact or with Vertical Fractures:					
P-CR-8	19	--	3.108	10,010	18,690
	24	44.8	3.206	17,420	17,935
P-CR-22	6	--	2.906	8,240	15,045
	11	--	3.069	8,515	15,045
	12	43.7	2.953	10,270	13,060
	18	41.1	2.913	9,020	10,655
	Average	43.2	3.026	10,580	15,070
Highly Fractured:					
P-CR-8	4	--	2.893	4,030	15,060
	6	--	2.787	4,545	--
	23	39.4	3.081	1,360	--
	Average	39.4	2.920	3,310	15,060

The amphibolites were quite dense, exhibiting an average specific gravity of approximately 3.0. These high densities were probably due to large quantities of hornblende (specific gravity, 2.9 to 3.2) present in the specimens.

Uniaxial compressive strengths exhibited by this core were generally rather low, particularly those yielded by the highly fractured specimens. Both the intact and vertically fractured amphibolites exhibited ultimate strengths averaging approximately 10,000 psi, indicating that the presence of vertical fractures had little effect, if any, on ultimate uniaxial compressive strength. The presence of well developed systems of fracture, however, appeared to greatly reduce the ultimate strength; highly fractured specimens generally exhibited strengths approximately one-third as large as those yielded by the vertically fractured and intact core.

Compressional wave velocities showed considerable variation, ranging from 10,000 to 19,000 fps. This wide range of values was possibly due to the combined effects of the bands, fractures, and large biotite inclusions present in much of the amphibolite.

Both of the specimens for which static and dynamic moduli were determined exhibited some hysteresis and, upon cycling, residual strain. Although the quantity of data available is insufficient to make specific comparisons, the static and dynamic constants determined for the amphibolite (tabulated on the following page) appear to be in

Hole No.	Specimen No.	Young's Modulus		Bulk Modulus		Shear Modulus		Poisson's Ratio	
		Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic
		10^6 psi	10^6 psi	10^6 psi	10^6 psi	10^6 psi	10^6 psi		
P-CR-8	24	8.2	10.5	3.7	8.5	3.6	4.1	0.13	0.29
P-CR-22	11	5.7	7.6	2.3	5.4	2.7	3.0	0.08	0.26

the same general range as the values for the gneiss.

3.5 MISCELLANEOUS CORES

Four specimens tested varied appreciably in composition and/or physical condition from the three principal rock types previously discussed. All of these specimens exhibited physical test results characteristic of rather marginal materials. A summary of the results is presented below.

Hole No.	Specimen No.	Rock Type	Schmidt No.	Specific Gravity	Ultimate Uniaxial Compressive Strength	Compressional Wave Velocity
					psi	fps
P-CR-22	8	Mica schist	42.3	2.983	15,840	18,895
	9	Mica schist	52.7	2.901	9,030	14,150
P-CR-46	2	Moderately weathered gneiss	34.7	2.647	12,545	15,560
	11	Disrupted quartz vein	45.6	2.709	8,575	14,780

CHAPTER 4

SPECIAL TEST RESULTS

4.1 ANISOTROPY TESTS

Eleven rock specimens were selected and prepared for determination of compressional (dilatational) and shear velocities according to the ASTM proposed "Standard Method of Test for Laboratory Determination of Ultrasonic Pulse Velocities and Elastic Constants of Rock." The NX-diameter specimens were cut to lengths of 2 inches and ground on the ends to a tolerance of 0.001 inch. Four 1/2-inch-wide strips were also ground down the sides of the cylindrical surface at 90-degree angles. The velocities, densities, and dimensions were measured as specified in the proposed test method.

Results of the velocity determinations are given in Table 4.1. Compressional and shear velocities were consistently higher for the gneiss and amphibolite, possibly due to the large porosities characteristic of many sandstones.

Deviations from the average compressional wave velocities were much lower for the gneiss and amphibolite, indicating considerably greater degrees of anisotropy in the sandstones. This anisotropy was probably due to a combination of factors, such as variation in nature and degree of cementing present, variation in grain size, and the presence of bedding.

The anisotropy is in the vertical direction (generally normal to the bedding). Wave velocities exhibited by the gneiss and amphibolite were quite uniform, apparently affected only slightly, if at all, by the varying degrees of foliation and banding present.

A compilation of the elastic properties computed from the compressive and shear velocities and the specific gravity is given in Table 4.2. However, discretion must be used in utilizing the moduli results as experimental errors are introduced when the differences in velocities are significant. The proposed ASTM test method states that the equations for computation of elastic moduli should not be used if "any of the three compressional wave velocities varies by more than 2 percent from their average value. The error in E and G due to both anisotropy and experimental error then does not exceed 6 percent." Naturally, the effect of the error is compounded by greater differences in the three-directional velocity measurements.

The 2 percent allowable deviation proposed by ASTM appears to be unrealistic since laboratory-determined values of compressional and shear wave velocities are reproducible within a deviation from the average of only 2 to 3 percent. Thus, it would appear that the point of division between isotropy and anisotropy would more realistically be in the range of 5 to 8 percent deviation from the average. It should be kept in mind, however, that this greater deviation

would also allow a larger error in the computed values of E and G .

To evaluate the effect of anisotropy on a rock mass, one should determine the state of stress expected or applied. The effect of elastic anisotropy on the stress distribution is greatest for a uniaxial state of stress, a state which exists in very little massive rock. Reference 4 indicates that if the stress field is hydrostatic and the ratio of moduli due to anisotropy is approximately 2, the maximum difference in stress for the isotropic and anisotropic cases would be only 10 to 15 percent. Reference 4 further states

> It can be inferred that for most rock, the effects of elastic anisotropy are no larger than the normal variations in rock strength and, hence, they can be neglected. The most likely exceptions to this generalization would be strongly foliated metamorphic rocks, such as micaceous schists,...where the moduli of elasticity often differ by a factor greater than two.

4.2 COMPARATIVE TENSILE TESTS

Eleven NX-diameter rock specimens were selected to represent the variation of rock type present in the core. The specimens were prepared and tested for tensile strength according to the ASTM proposed "Standard Method of Test for Direct Tensile Strength of Rock Core Specimens." For comparative purposes, tensile splitting tests were conducted on specimens cut adjacent to the direct tensile test specimens. Test results are given in Table 4.3.

The banded and/or foliated nature of the gneiss could possibly

explain the large differences in strength obtained from the two test methods. This banding and foliation was frequently perpendicular to the direction of stressing in the direct test. Therefore, the direct tensile strengths should be the minimum strengths obtained. The splitting test, however, stresses the specimen in a manner such that the intrinsic strength of the bands is developed. Therefore, one would normally utilize the direct tensile strength as the more conservative value.

The fine- and coarse-grained sandstones exhibited relatively uniform direct and indirect test results, possibly indicative of relatively uniform, directionally independent tensile characteristics. The medium-grained sandstone, however, yielded test results which were quite different for the two different methods, possibly due to effects produced by bedding and crossbedding or to variation in nature and degree of cementation as noted in the petrographic examination.

4.3 POROSITY TESTS

Porosity, herein defined as the volume of the voids expressed as a percentage of total volume, was determined for three sandstone specimens. These three specimens represented the variation in grain size found in the sandstone core, and exhibited porosities which were low to moderate by comparison with the range of values indicated in literature. Test results are given in Table 4.3.

4.4 PETROGRAPHIC EXAMINATION

4.4.1 Samples. Six boxes of NX core from holes in Clinton, Franklin, Essex, and Warren Counties, New York, were received for testing in October 1969. Each box contained about 15 feet of core which represented several depths to 200 feet.

The cores were inspected to select representative pieces from all significant rock types for petrographic examination. The cores are described below:

1. Hole P-CR-8. The core ranged from fine- to coarse-grained metamorphics. Gray-green, coarse-grained garnet gneiss; dark-gray-and-red, medium-grained amphibolite; and dark-gray, medium-grained amphibolite were present.

Sections 1, 2, 8, 10 through 15, 17, and 18 were gray-green, coarse-grained gneiss. Most of these sections contained several fractures. Sections 3 through 7, 9, and 16 were dark-gray amphibolite. Most of the sections contained sealed fractures. Sections 19 through 24 were iron-stained, severely sheared amphibolite.

Several sections of amphibolite contained large biotite inclusions. Most of the open fractures were slickensided.

2. Hole P-CR-22. The core ranged from poorly banded to well banded gneiss.

Sections 1 through 5, 7, 10, 13, and 15 through 22 were well banded, dark-gray to black and white, medium-grained,

hornblende-biotite gneiss. Sections 6, 11, 12, 14, and 18, containing more hornblende, were amphibolite. The bands ranged from medium- to coarse-grained. Sections 6 and 10 through 13 contained large lens-like masses of feldspar and quartz that disrupted the banding. Sections 8 and 9 were black, medium-grained mica schist. Section 9 appeared to be altered, and Section 8 appeared to be fresh.

Most of the sections were not fractured, and only Section 9 appeared to be altered.

3. Hole P-CR-46. The core ranged from intact, weakly banded to severely fractured gneiss in which banding could not be detected on the scale of an NX core. The gneiss ranged from dark gray to light gray, and there were several calcite and fluorite veins present.

Sections 1 through 5, 8, 11, 13 through 16, and 18 were severely sheared and showed considerable offsets along shear planes. Sections 1 through 4 were slightly weathered. Sections 6, 7, 20, and 21 had incipient fractures. Sections 9, 10, 12, 17, and 19 were poorly banded but were not severely sheared.

4. Hole P-CR-64. The core was red quartz sandstone that ranged from coarse- to fine-grained. The upper 90 feet of the hole was fine- to medium-grained, and the remainder of the hole was predominately medium- to coarse-grained. Six sections contained vertical fractures; the remaining sections were intact.

5. Hole P-CR-72. The core was white, fine-grained quartz

sandstone and gray, medium-grained quartz sandstone. The entire core appeared unweathered and massive.

Sections 1 through 8 and 18 were white, fine-grained sandstone. This rock was not porous and was not fractured. Sections 7 and 8 were iron-stained. Sections 9 through 17, 19, and 20 were gray, medium-grained sandstone. Sections 10, 19, and 20 were iron-stained.

6. Hole P-CR-81. The core was pink, medium-grained gneiss; dark-gray, medium-grained gneiss; and black, fine-grained basalt.

The pink gneiss had well developed foliation and very few joints or fractures. Sections 1 through 12 were pink gneiss. Section 13 was black basalt. The section was intact. Sections 14 and 16 through 24 were dark-gray gneiss. This rock did not have well developed foliation. Sections 18 through 21 contained high-angle fractures, and the remaining sections were massive.

The sections selected for petrographic examination were:

Hole No.	Concrete Division Serial No.	Section No.	Approximate Depth	Rock Description
			feet	
P-CR-8	SAMSO-11, DC-4	7	77	Gray-green, coarse-grained garnet gneiss
		10	93	Dark-gray, medium-grained amphibolite

(Continued)

Hole No.	Concrete Division Serial No.	Section No.	Approximate Depth	Rock Description
			feet	
		20	165	Dark-gray and red, medium-grained amphibolite
P-CR-22	SAMSO-11, DC-5	13	116	Black and white gneiss with large masses of feld-spar and quartz
		14	127	Well banded, dark-gray, medium-grained amphibolite
P-CR-46	SAMSO-11, DC-6	12	124	Gray, poorly banded gneiss
		13	131	Faulted, light-gray gneiss
P-CR-64	SAMSO-11, DC-2	11	71	Red, fine-grained sandstone
		24	167	Red, coarse-grained sandstone
P-CR-72	SAMSO-11, DC-1	2	42	White, fine-grained sandstone
		11	133	Gray, medium-grained sandstone
P-CR-81	SAMSO-11, DC-3	12	103	Pink, medium-grained gneiss
		22	177	Dark-gray, medium-grained gneiss

4.4.2 Test Procedure. Each piece of core was sawed axially. One sawed surface of each piece was polished and photographed. Composite samples were obtained from the whole length or from selected portions from the remaining half of each piece. The composite samples were ground to pass a No. 325 sieve (44 μm). X-ray diffraction (XRD) patterns were made of each sample as a tightly packed powder. All XRD patterns were made using an XRD-5 diffractometer with nickel-filtered copper radiation. The samples X-rayed are listed below:

Hole No.	Section No.	Description of X-Ray Sample
P-CR-8	7	Entire length of core
	10	Entire length of core
	20	Entire length of core
P-CR-22	13	Entire length of core
	14	Entire length of core
P-CR-46	12	Entire length of core
	13	Entire length of core except calcite-fluorite vein was sampled
P-CR-64	11	Entire length of core
	24	Entire length of core
P-CR-72	2	Entire length of core
	11	Entire length of core
P-CR-81	12	Entire length of core
	22	Entire length of core

Small portions of the powdered samples were tested with dilute hydrochloric acid and with a magnet to determine whether carbonate

minerals or magnetite were present.

The polished surface of each section was examined with a stereo-microscope. Thin sections were prepared from each section of core and examined with a polarizing microscope. A point-count modal analysis was made on each thin section in which 500 points were counted.

4.4.3 Results. The cores can be divided into three groups: sandstones, granitic gneisses, and amphibolites. The sandstones were taken from the Upper Cambrian Potsdam formation in extreme northern New York. The remainder of the rocks were taken from the metamorphic sequence that makes up the bulk of the Precambrian Adirondack Mountains of upstate New York (Reference 5). The rocks in the cores are discussed below. The modal composition of each type is shown in Tables 4.4, 4.5, and 4.6 and the bulk composition by XRD in Tables 4.7, 4.8, and 4.9.

Sandstones. Cores P-CR-64 and P-CR-72 (Figures 4.1 and 4.2) consisted of sandstone which ranged from a white, fine-grained subarkose to a gray, medium-grained quartzarenite (classification according to Reference 6). The major constituents were quartz and microcline, and the cements were silica, chlorite, and hematite. The bedding planes were approximately horizontal. Graded bedding was common in some sections.

Half of Section 11 of Core P-CR-64 (Section 11a, Figure 4.1) was cross-bedded sandstone with hematite cement. Microcline formed 11

percent of the detrital grains causing the rock to be classified as a subarkose. There was considerable variation in grain size, though most of the grains were within the limits of medium grain size. Most of the grains were subangular.

The remaining half of the section (11b) was also a subarkose containing 11 percent microcline. This half had normal bedding; the grains were equidimensional, and the cement was chamosite. The chamosite gave this half of the section a green color while the hematite gave the other half (11a) a red color.

Section 24 of Core P-CR-64 (Figure 4.1) was a red, conglomeratic subarkose containing quartz, microcline, and magnetite cemented by hematite. This section had the widest range in grain size from coarse to fine; the highest microcline content, 13 percent; and the greatest percentage of cement, which was 15 percent. Most of the coarse grains were fractured quartz pebbles. This rock was not tightly cemented and was more porous than the other sandstones. The section had graded bedding.

Section 2 of Core P-CR-72 (Figure 4.2) was white, fine-grained sandstone with microcline forming 8 percent of the detrital grains which caused it to be classified as subarkose. Bedding traces were slightly inclined and accented by minor amounts of heavy minerals. The detrital grains were equigranular, rounded, and tightly cemented.

Section 11 of Core P-CR-72 (Figure 4.2) was a light-gray,

medium-grained, silica-cemented quartz arenite. The section contained graded bedding with the coarsest fraction being medium-grained. Bedding was accented by thin clay layers that were partially disrupted during compaction.

Gneisses. Cores P-CR-46 and P-CR-81, and parts of Cores P-CR-8 and P-CR-22 were gneisses which had similar compositions but showed a wide range in metamorphic fabric, grain size, and color (Figures 4.3, 4.4, and 4.5). The diverse fabric and texture of these sections suggest that the uniform mineral composition may have resulted from homogenization during metamorphism rather than from originally similar composition. The uniform degree of metamorphism indicated by the mineralogy, the proximity of the samples, and the lack of similar relic structures or textures further supports this hypothesis.

Section 7 of Core P-CR-8 was gray-green and gray-red, coarse-grained, garnet gneiss (Figure 4.3). The section was severely fractured and pyrite had been introduced along fracture planes, sealing some of them; but some open fractures were present. Biotite was partly altered to chlorite; some of the mica was bent or bent and broken. This was the most altered rock and the most fractured rock found in the cores. It differed from the other gneisses in that it contained almost no microcline and garnet was a major constituent.

Section 13 of Core P-CR-22 had a matrix of black and white, medium-grained biotite gneiss with several large, spindlelike masses

or augen of quartz, microcline, and plagioclase, elongated parallel to the foliation of the matrix (Figure 4.3). The foliation bent around the augen. The augen and the matrix differed considerably in composition, but the composition of the whole section was similar to the compositions of the gneisses in Cores P-CR-46 and P-CR-81.

Section 12 of Core P-CR-46 was a black and white, coarse-grained biotite granite gneiss. This gneiss did not have an obvious planar structure (Figure 4.4), but there was a weak horizontal trend of the biotite flakes. Small crystals of garnet were scattered randomly throughout the section. The structure is not interpretable on the scale of this core.

Section 13 of Core P-CR-46 was a white and gray-green, medium- to coarse-grained gneiss. A poorly expressed foliation that dipped about 45 degrees from the vertical was detectable on the drilled surface of the core. This section contained a calcite-fluorite vein that had been folded and faulted. The vein cuts the foliation, which indicates the foliation was developed before the faulting occurred.

Section 12 of Core P-CR-81 was a gray-pink, medium-grained gneiss containing about 5 percent more plagioclase and 5 percent less microcline than Section 13 of Core P-CR-46 or Section 22 of Core P-CR-81. This section did not contain any biotite but did contain a small amount of hornblende. The foliation dipped at about 30 degrees; no shear planes or fractures were seen (Figure 4.5).

Section 22 of Core P-CR-81 was gray, medium-grained, perthitic gneiss with no apparent foliation (Figure 4.5). The major constituent of the section was perthitic feldspar containing about one quarter microcline and three quarters plagioclase. Grains containing only one feldspar were very rare. Anhedral grains of pyroxene and magnetite were common throughout the section.

Amphibolites. Parts of Cores P-CR-8 and P-CR-22 were classed as amphibolites. These rocks were dark, medium-grained amphibole, biotite, and plagioclase gneisses that ranged from severely sheared and fractured to intact. Sulfides had been introduced along gneissic banding and in fractures.

Section 10 of Core P-CR-8 was a dark-green and black, medium-grained hornblende gneiss. The foliation dipped at a low angle (Figure 4.6), and minor vertical fractures were present. The hornblende and plagioclase grains were intact and only slightly altered. Magnetite grains were scattered randomly throughout the section, and pyrite was found only in discrete layers in the section.

Section 20 of Core P-CR-8 was dark-green and red, medium-grained amphibolite with minor alteration to hematite along fractures. The section was similar to Section 10 of this core but lacked well developed foliation (Figure 4.6). This section contained more magnetite than Section 10 and also contained a small amount of chlorite that appeared to have formed by alteration of biotite.

Section 14 of Core P-CR-22 was black and white, medium-grained, biotite-rich amphibolite with a well developed foliation produced by parallel alinement of biotite and hornblende (Figure 4.7). This section contained more biotite than any of the other sections of amphibolite, and the plagioclase was severely altered to sericite. This section also contained a small amount of carbonate introduced along minor fractures.

4.4.4 Summary. Petrographic examination of 13 sections of core from six holes in the Adirondack Mountains area of northern New York State indicated that there were three rock types represented: sandstones, granite gneisses, and amphibolites. The sandstones and the granite gneisses were the most abundant rock types in the cores. Differences in the compressive strengths of the sandstones appear to have arisen from differences in grain size and porosity among the rocks tested. Differences in compressive strengths and elastic properties among the remaining rock types appear to have arisen from the number and inclination of fractures, whether the fractures were open or sealed, and the degree of alteration of the rocks. The mineral compositions are summarized in Tables 4.4 through 4.9, and the sections examined are illustrated in Figures 4.1 through 4.7.

TABLE 4.1 VELOCITY DETERMINATIONS

		Velocity[a] Compressional	Velocity[a] Shear
		fps	fps
Hole P-CR-8, Specimen 5:			
Fractured amphibolite		18,470	9,520
Depth: 66 feet		19,330	11,740
Specific gravity: 2.885		20,230	11,420
Compressional deviation:[b] 4.6 pct			
	Average	19,340	10,890
Hole P-CR-8, Specimen 15:			
Fractured gneiss		18,890	10,240
Depth: 131 feet		18,850	10,680
Specific gravity: 3.004		20,440	11,340
Compressional deviation: 5.4 pct			
	Average	19,390	10,750
Hole P-CR-22, Specimen 1:			
Well banded biotite gneiss		18,130	9,020
Depth: 10 feet		18,900	10,580
Specific gravity: 2.693		18,580	10,430
Compressional deviation: 2.3 pct			
	Average	18,540	10,010
Hole P-CR-22, Specimen 7:			
Well banded biotite gneiss		19,400	10,870
Depth: 64 feet		18,300	10,060
Specific gravity: 2.695		18,080	9,940
Compressional deviation: 4.4 pct			
	Average	18,590	10,290
Hole P-CR-46, Specimen 3:			
Severely sheared gneiss		19,010	10,150
Depth: 54 feet		18,740	10,520
Specific gravity: 2.665		18,850	10,520
Compressional deviation: 0.7 pct			
	Average	18,870	10,400
Hole P-CR-46, Specimen 6:			
Fractured gneiss		19,350	9,850
Depth: 71 feet		19,180	10,520
Specific gravity: 2.712		19,380	10,430
Compressional deviation: 0.6 pct			
	Average	19,300	10,270
Hole P-CR-64, Specimen 20:			
Medium-grained sandstone		10,620	8,580
Depth: 142 feet		13,090	7,840
Specific gravity: 2.490		12,370	8,240
Compressional deviation: 11.7 pct			
	Average	12,030	8,220
Hole P-CR-64, Specimen 22:			
Coarse-grained sandstone		11,760	9,870
Depth: 150 feet		14,430	8,500
Specific gravity: 2.596		15,190	8,460
Compressional deviation: 14.7 pct			
	Average	13,790	8,940
Hole P-CR-72, Specimen 5:			
Fine-grained sandstone		11,790	9,010
Depth: 74 feet		14,140	9,000
Specific gravity: 2.524		13,990	9,060
Compressional deviation: 11.4 pct			
	Average	13,310	9,020
Hole P-CR-81, Specimen 9:			
Well-foliated gneiss		19,260	10,470
Depth: 84 feet		19,290	10,910
Specific gravity: 2.755		19,920	11,140
Compressional deviation: 2.2 pct			
	Average	19,490	10,840
Hole P-CR-81, Specimen 16:			
Poorly foliated gneiss		20,420	11,820
Depth: 129 feet		20,500	11,650
Specific gravity: 2.734		20,270	11,690
Compressional deviation: 0.6 pct			
	Average	20,400	11,720

[a] First velocity listed is in axial (longitudinal) direction; other two are on mutually perpendicular, diametral (lateral) axes.
[b] Maximum percent deviation from the average of the compressional wave velocity.

TABLE 4.2 DYNAMIC ELASTIC PROPERTIES

Hole No.	Specimen No.		Modulus			Poisson's Ratio
			Young's	Shear	Bulk	
			10^6 psi	10^6 psi	10^6 psi	
P-CR-8	5		9.3	3.5	8.6	0.32
			12.9	5.4	7.4	0.21
			12.8	5.1	9.2	0.27
		Average	11.7	4.7	8.4	0.27
P-CR-8	15		11.1	4.3	8.9	0.29
			11.8	4.7	8.3	0.26
			13.1	5.1	10.3	0.29
		Average	12.0	4.7	9.2	0.28
P-CR-22	1		7.9	3.0	8.0	0.34
			10.3	4.1	7.5	0.27
			10.0	4.0	7.3	0.27
		Average	9.4	3.7	7.6	0.29
P-CR-22	7		10.9	4.3	8.0	0.27
			9.4	3.7	7.2	0.28
			9.2	3.6	7.1	0.28
		Average	9.8	3.9	7.4	0.28
P-CR-46	3		9.6	3.7	8.0	0.30
			10.0	4.0	7.3	0.27
			10.1	4.0	7.4	0.27
		Average	9.9	3.9	7.6	0.28
P-CR-46	6		9.4	3.6	9.0	0.33
			10.3	4.0	8.0	0.28
			10.3	4.0	8.4	0.30
		Average	10.0	3.9	8.5	0.30
P-CR-64	20		2.8	2.5	--[a]	--[a]
			5.0	2.1	3.0	0.22
			5.0	2.3	2.1	0.10
		Average	4.3	2.3	2.6	0.16
P-CR-64	22		2.1	3.4	--[a]	--[a]
			6.2	2.5	3.9	0.23
			6.4	2.5	4.7	0.28
		Average	4.9	2.8	4.3	0.26
P-CR-72	5		4.4	2.8	--[a]	--[a]
			6.4	2.8	3.1	0.16
			6.4	2.8	2.9	0.14
		Average	5.7	2.8	3.0	0.15
P-CR-81	9		10.5	4.1	8.3	0.29
			11.1	4.4	7.9	0.26
			11.7	4.6	8.6	0.27
		Average	11.1	4.4	8.3	0.27
P-CR-81	16		12.8	5.1	8.5	0.25
			12.6	5.0	8.8	0.26
			12.6	5.0	8.4	0.25
		Average	12.7	5.0	8.6	0.25

[a] Due to the unrealistically high shear velocity to compressional velocity ratio obtained, the bulk modulus and Poisson's ratio could not be accurately determined.

TABLE 4.3 TENSILE STRENGTH AND POROSITY DETERMINATIONS

Hole No.	Specimen No.	Depth	Tensile Strength		Porosity	Direct/Splitting Strength	Core Log Description
			Splitting	Direct			
		feet	psi	psi	pct	pct	
P-CR-8	5	66	1,560	820	--	53	Fractured gneiss
P-CR-8	15	131	970	350	--	36	Fractured amphibolite
P-CR-22	1	10	1,320	320	--	24	Well banded gneiss, nearly horizontal banding
P-CR-22	7	64	1,700	520	--	30	Well banded gneiss, nearly horizontal banding
P-CR-46	3	54	1,660	330	--	20	Severely sheared gneiss
P-CR-46	6	71	1,500	250	--	17	Gneiss with incipient fractures
P-CR-64	20	142	1,260	340	2.7	27	Medium-grained sandstone
P-CR-64	22	150	510	340	5.2	67	Coarse-grained sandstone
P-CR-72	5	74	490	400	5.7	82	Fine-grained sandstone
P-CR-81	9	84	1,690	570	--	33	Pink, well foliated gneiss
P-CR-81	16	129	1,790	550	--	31	Gray, poorly foliated gneiss
	Average of gneiss		1,603	480		30	

TABLE 4.4 MODAL COMPOSITION OF SANDSTONES BASED ON 500 POINT COUNTS PER THIN SECTION

Constituent	P-CR-64 Section 11a	P-CR-64 Section 11b	P-CR-64 Section 24	P-CR-72 Section 2	P-CR-72 Section 11
Quartz	85	76	64	86	94
Microcline	11	11	13	8	--
Chlorite	--	10[a]	1	--	--
Magnetite	--	3	7	--	--
Hematite	4[a]	--	15[a]	--	--
Silica cement	--	--	--	6	6

[a] As cement.

TABLE 4.5 MODAL COMPOSITION OF GNEISSES BASED ON 500 POINT COUNTS PER THIN SECTION

Constituent	P-CR-8 Section 7	P-CR-22 Section 13	P-CR-46 Section 12	P-CR-46 Section 13	P-CR-81 Section 12	P-CR-81 Section 22
Quartz	20	25	21	29	28	14
Microcline	1	23	27	29	23	66[a]
Plagioclase	25	25	28	29	33	
Hornblende	--	5	--	--	6	4
Pyroxene	--	--	--	--	--	7
Biotite	12	18	19	Trace	--	--
Chlorite	12	--	--	12	--	--
Magnetite	1	Trace	Trace	Trace	8	8
Pyrite	3	--	--	--	--	--
Hematite	--	--	--	--	Trace	--
Garnet	24	--	4	Trace	1	--
Zircon	--	Trace	Trace	Trace	--	--
Apatite	--	Trace	Trace	Trace	--	Trace
Carbonate	2	--	Trace	Trace	Trace	Trace
Fluorite	--	--	--	Trace	--	--

[a] Perthite, about 1/4 microcline and 3/4 plagioclase.

TABLE 4.6 MODAL COMPOSITION OF AMPHIBOLITES BASED ON 500 POINT COUNTS PER THIN SECTION

Constituent	P-CR-8 Section 10	P-CR-8 Section 20	P-CR-22 Section 14
Quartz	1	--	6
Plagioclase	49	35	22
Hornblende	36	48	30
Pyroxene	9	--	--
Biotite	--	--	29
Chlorite	--	3	--
Magnetite	2	6	5
Pyrite	3	--	1
Hematite	--	8	--
Apatite	--	--	Trace
Zircon	--	--	Trace

TABLE 4.7 BULK COMPOSITIONS OF SANDSTONES BASED ON X-RAY DIFFRACTION RESULTS

Compared to P-CR-72, Section 2.

Constituent	P-CR-64 Section 11a	P-CR-64 Section 11b	P-CR-64 Section 24	P-CR-72 Section 2	P-CR-72 Section 11
Quartz	Same	Slightly less	Much less	Abundant	Slightly more
Microcline	Same	Same	Same	Minor	--
Chlorite	--	Minor	Trace	--	--
Hematite	Trace	--	Minor	--	--
Magnetite	--	Trace	Trace	--	--
Biotite	--	--	--	--	Trace

TABLE 4.8 BULK COMPOSITIONS OF GNEISSES BASED ON X-RAY DIFFRACTION RESULTS

Compared to P-CR-46, Section 12.

Constituent	P-CR-8 Section 7	P-CR-22 Section 13	P-CR-46 Section 12	P-CR-46 Section 13	P-CR-81 Section 12	P-CR-81 Section 22
Quartz	Same	Same	Abundant	Same	Slightly more	Much less (minor)
Microcline	Much less (trace)	Same	Abundant	Same	Same	Much less
Plagioclase	Same	Same	Abundant	Same	Slightly more	Much more
Biotite	Slightly less (minor)	Same	Abundant	Very much less (trace)	--	--
Chlorite	Minor	--	--	Minor	--	--
Hornblende	--	Minor	--	--	Minor	Minor
Pyroxene	--	--	--	--	--	Minor
Magnetite	Trace	Trace	--	--	Minor	Minor
Garnet	Abundant, much more	--	Minor	Much less (trace)	--	Much less (trace)
Carbonate	--	--	Trace	Same	--	--
Fluorite	--	--	--	Trace	--	--
Chalcopyrite	Trace	--	--	--	--	--

TABLE 4.9 BULK COMPOSITION OF AMPHIBOLITES BASED ON X-RAY DIFFRACTION RESULTS

Compared to P-CR-8, Section 20.

Constituent	P-CR-8 Section 10	P-CR-8 Section 20	P-CR-22 Section 14
Quartz	Trace	--	Minor
Plagioclase	Slightly more	Abundant	Slightly less
Biotite	--	--	Abundant
Chlorite	--	--	--
Hornblende	Slightly less	Abundant	Slightly less
Pyroxene	Minor	--	--
Magnetite	Slightly less (trace)	Minor	Same
Pyrite	Trace	--	--
Hematite	--	Minor	--

Figure 4.1 Sandstone sections, Core P-CR-64. Section 24 shows conglomeratic textures. Large gray pebbles are quartz. Section 11 shows medium-grained particles cemented by hematite (a) and chlorite (b).

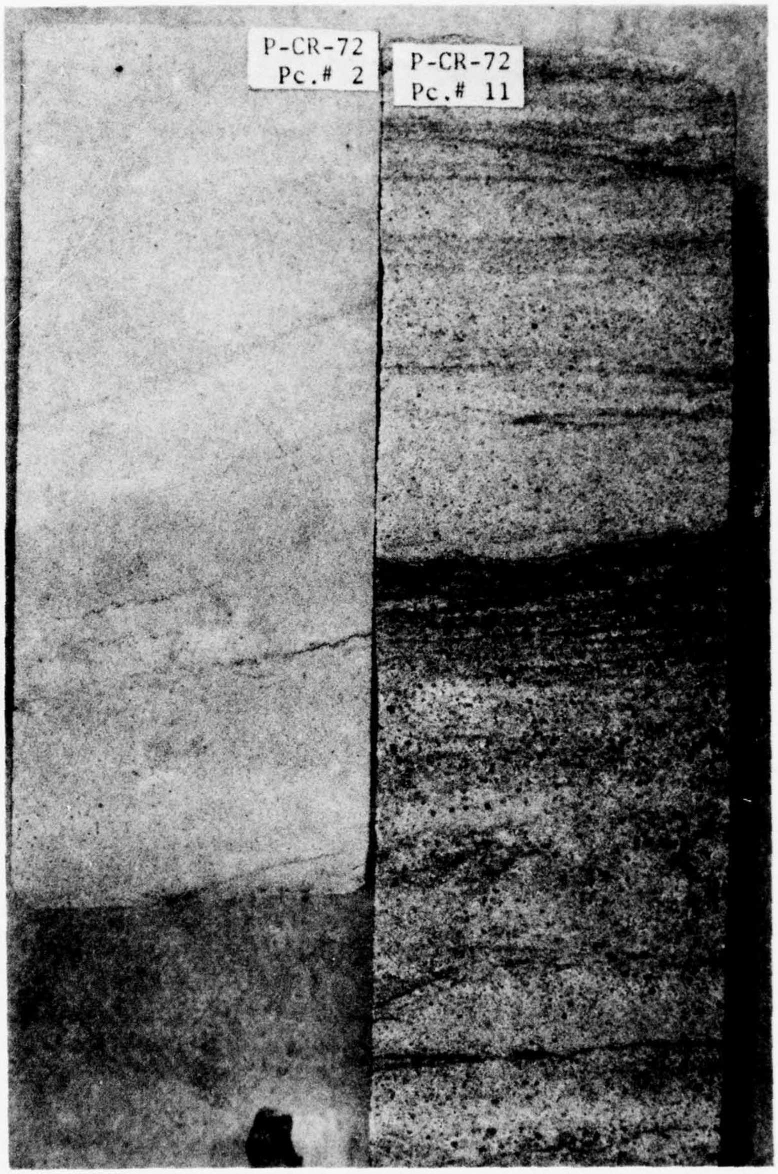


Figure 4.2 Sandstone sections, Core P-CR-72. Section 2 shows fine-grained equigranular texture and slightly inclined bedding. Section 11 shows medium- to fine-grained texture and horizontal bedding. Narrow black lines are clayey layers.

Figure 4.3 Gneiss sections, Cores P-CR-8 and P-CR-22. Section 13 shows large white augen of quartz, plagioclase, and microcline elongated parallel to the foliation. The foliation bends around the augen. Section 7 shows several fractures (narrow white and black lines) and pyrite introduced along the fractures (white specks near top and bottom).

Figure 4.4 Gneiss sections, Core P-CR-46. Section 12 shows lack of planar structures. Black grains are biotite and large white masses are quartz. Section 13 shows folded and faulted calcite-fluorite vein (white area lower right) and reduced grain size around the vein due to shearing.

Figure 4.5 Gneiss sections, Core P-CR-81. Section 22 shows medium-grained texture and lack of foliation. Small white specks are magnetite. Section 12 shows grain size similar to 22 but has well developed foliation.

Figure 4.6 Amphibolite sections, Core P-CR-8. Section 20 shows medium-grained amphibolite with several fractures (narrow white lines). Small white specks are magnetite. Section 10 shows grain size similar to 20 but has a nearly horizontal foliation which is accented by pyrite grains (white specks).

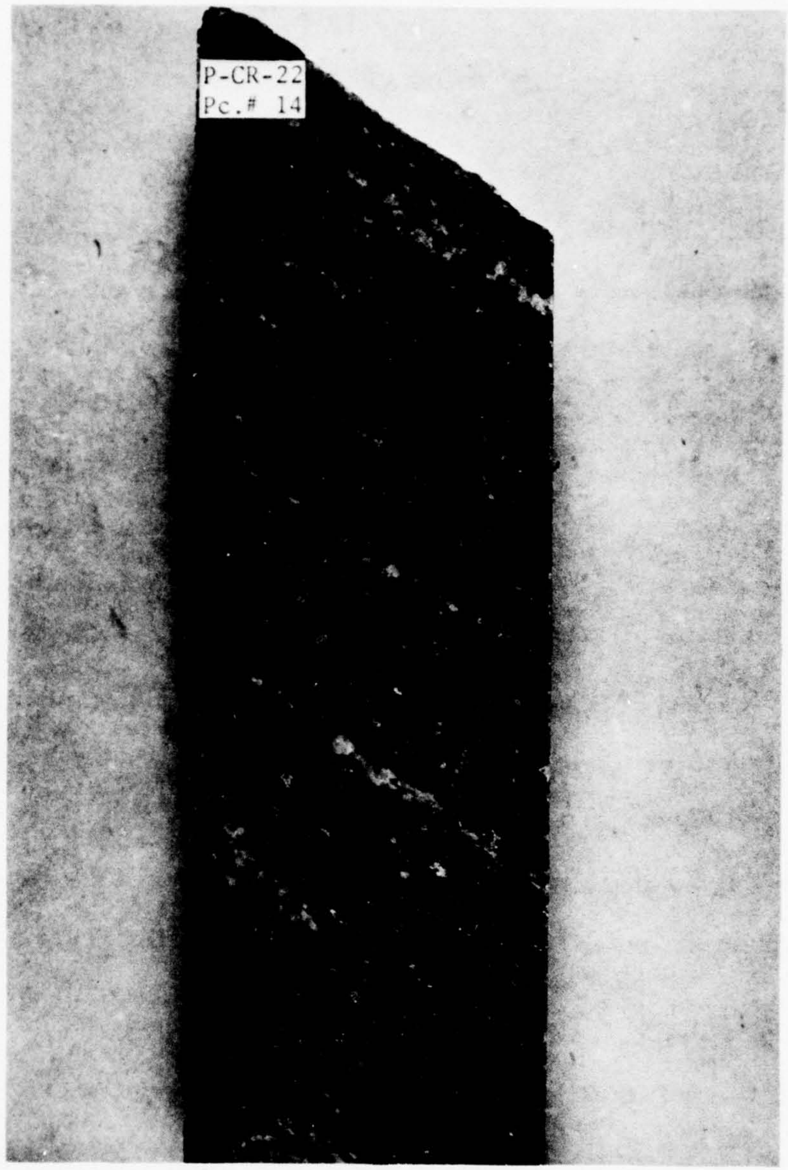


Figure 4.7 Amphibolite section, Core P-CR-22. Section 14 shows well developed foliation due to parallel alinement of hornblende and biotite.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

5.1 DISCUSSION

Due to the rather wide range of physical properties exhibited by the various materials received from the Plattsburgh study area, it was felt that a hole-to-hole evaluation of the area would be appropriate. The rock quality chart (Figure 5.1) illustrates the relative qualities (based on ultimate uniaxial compressive strengths) of the individual test specimens as well as the entire holes.

The sandstone received from Holes P-CR-64 and P-CR-72 was consistently competent over the entire range of depths. Holes P-CR-22 and P-CR-81 yielded rock of marginal to good quality, with the majority of marginal quality material being petrographically identified as amphibolite. Holes P-CR-8 and P-CR-46 contained reasonably large segments of poor and marginal material at various depths.

The locations of drill holes are shown in Figure 5.2.

5.2 CONCLUSIONS

Based on physical properties exhibited by the rock core specimens tested from the Plattsburgh study area, the following conclusions appear justified:

1. The core received from the Plattsburgh area was predominately

quartz sandstone and granite gneiss with small amounts of amphibolite and mica schist.

2. Based on physical properties exhibited, several distinct groups of material were represented: (1) fine-, medium-, and coarse-grained quartz sandstones, (2) poorly banded intact or incipiently fractured gneiss, (3) well banded intact or incipiently fractured gneiss, (4) gneiss containing prominent horizontal and/or vertical fractures, (5) gneiss containing well developed systems of fracture, critically oriented fractures, or sealed joints, (6) amphibolite either intact or with vertical fractures, (7) highly fractured amphibolite, and (8) miscellaneous cores, i.e., two specimens of mica schist, one of black basalt, and one representing a disrupted quartz vein.

3. The sandstone from this area is a moderately porous, competent material, with the fine-grained rock being somewhat stronger than the medium- and coarse-grained rock.

4. The intact gneiss, and that containing incipient fractures, is competent rock. Banding apparently weakens the rock, but not drastically. The gneiss containing horizontal and/or vertical fractures is relatively competent, with an average ultimate compressive strength of approximately 14,000 psi. The gneiss containing well developed systems of fracture (highly fractured), sealed joints, or critically oriented fractures is generally incompetent.

5. The amphibolite is, at best, of marginal quality, and is frequently incompetent.

6. Three-directional compressional wave velocity tests conducted on representative specimens indicate that the gneiss is slightly anisotropic, while the sandstone is quite anisotropic (11.4 to 14.7 percent deviation from the average). The anisotropy is in the vertical direction (normal to bedding).

7. Elastic constants exhibited by the sandstones were rather low (common for sandstones) but were very uniform. Elastic constants yielded by the gneiss were generally higher than those exhibited by the sandstones, but were somewhat less consistent.

8. Evaluation of the Plattsburgh area on a hole-to-hole basis indicates that the sandstone received from Holes P-CR-64 and P-CR-72 was generally competent rock and appears to offer possibilities as a competent hard rock medium, if anisotropy is not a disqualifying quality. The granite gneiss received from Holes P-CR-22 and P-CR-81 would also, in spite of the presence of some material of marginal quality, appear to be relatively competent. The core received from Holes P-CR-8 and P-CR-46 contained significant amounts of incompetent material. More extensive investigations will be required in order to accurately assess the areas under consideration.

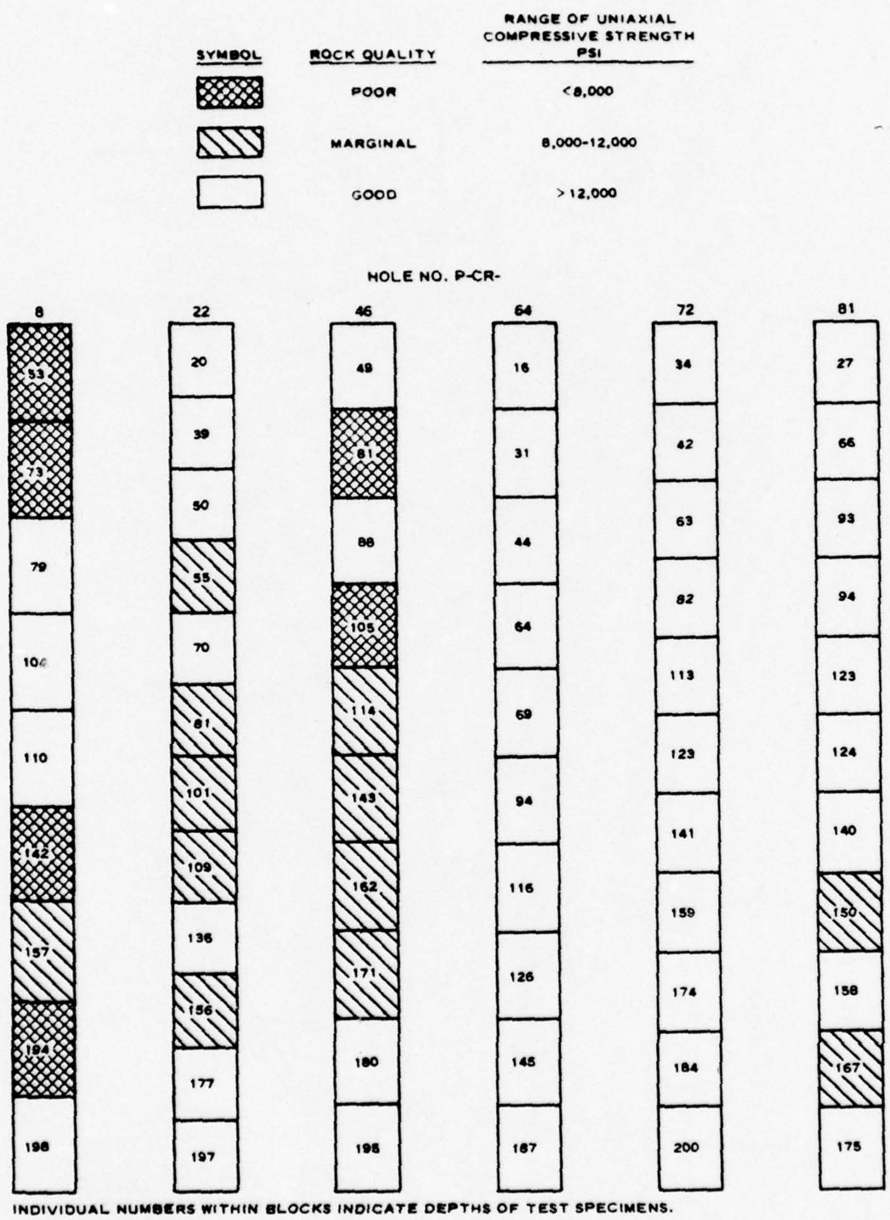


Figure 5.1 Depth versus quality for individual holes.

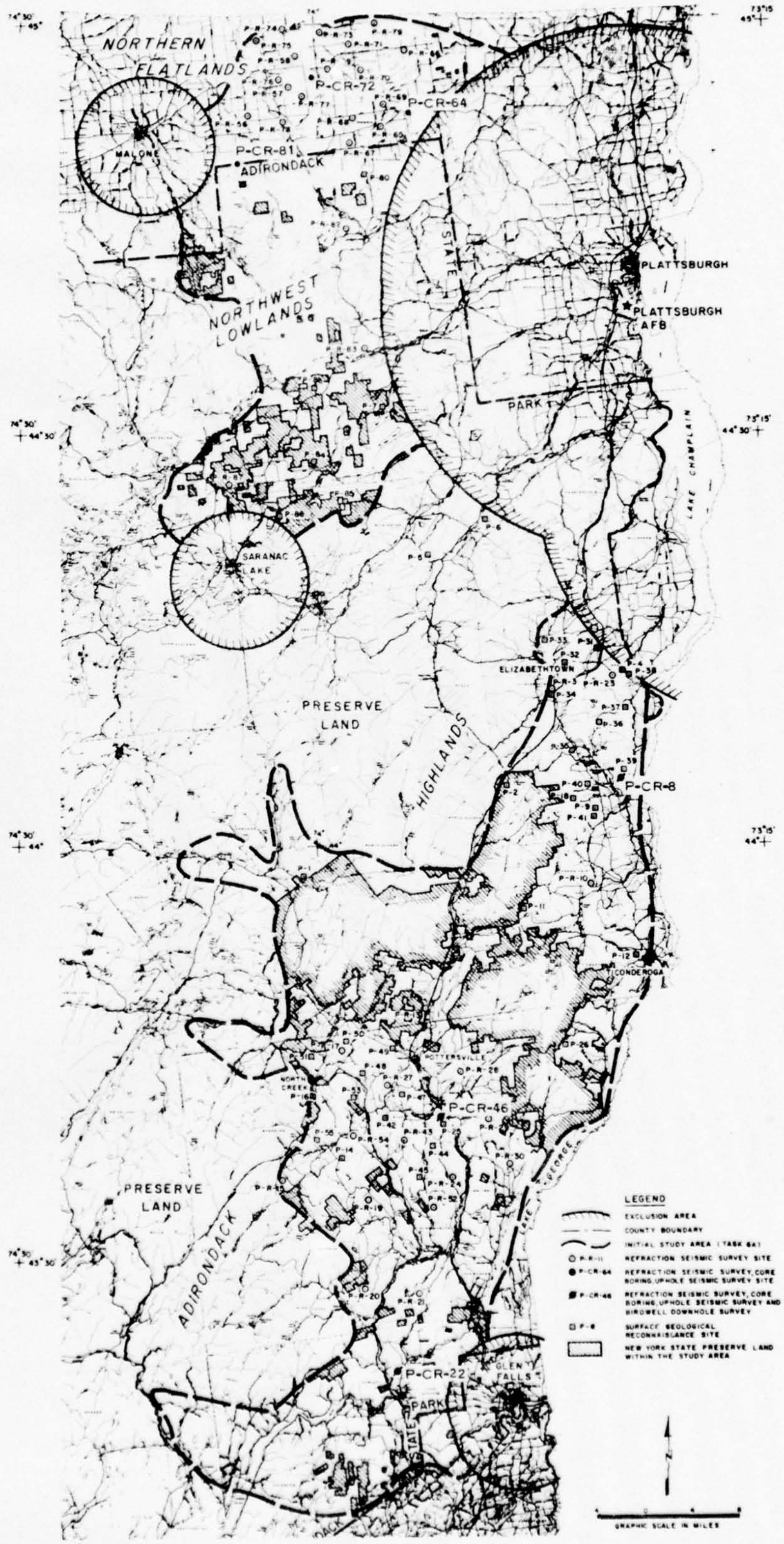


Figure 5.2 Field investigation sites.

APPENDIX A

DATA REPORT

Hole P-CR-8

31 October 1969

Hole Location: Essex County, New York

Core

1. The following core was received on 14 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	27
2	38
3	47
4	53
5	66
6	73
7	77
8	79
9	86
10	93
11	104
12	110
13	119
14	124
15	131
16	135
17	142
18	149
19	157
20	165
21	175
22	182
23	194
24	198

Description

2. The samples received were quite variable in appearance. According to the field log received with the core, the rock was identified as amphibolite, greenish-black garnetiferous hornblende gneiss, white and red garnetiferous quartz gneiss, and amphibolite migmatite. All specimens contained fractures, some of which were inclined at critical angles.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps**
4	Highly Fractured	53	2.893	--	4,030	15,060
6	Highly Fractured, Contained Large Biotite Inclusion	73	2.787	--	4,545	--
8	Vertical Fractures	79	2.741	42.6	14,790	14,770
11	Contained Vertical Fractures and Large Biotite Inclusion	104	3.051	--	14,330	16,610
12	Tightly Closed Vertical Fractures	110	2.776	40.1	13,580	15,095
17	Critical Angle Fractures	142	3.018	39.5	3,450	16,075
19	Tightly Closed Vertical Fractures	157	3.108	--	10,010	18,690
23	Highly Fractured	194	3.081	39.4	1,360	--
24	Tightly Closed Vertical Fractures	198	3.206	44.8	17,420	17,935
Average of Highly and Critically Fractured Specimens (4)			2.945	39.4	3,345	15,570
Average of Specimens Containing Vertical Fractures (5)			2.976	42.5	14,025	16,620

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

** Compressive wave velocities could not be determined for two specimens due to possibility of breakage.

Moduli of deformation

4. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 8, 11, and 24. Stress-strain curves are given in plates 1, 2, and 3. All specimens were cycled at 2500 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
8	7.1	4.2	2.9	8,880	0.22
11	10.5	5.3	4.5	10,490	0.17
24	10.5	8.5	4.1	9,700	0.29
		Static Tests			
8	6.7	3.3	2.9	--	0.16
11	7.8	4.5	3.2	--	0.21
24	8.2	3.7	3.6	--	0.13

All of the rock tested herein is apparently rather rigid material. The initial erratic behavior of the vertical strain gages on specimen No. 11 was possibly due to the location of the strain gages over high-angle fractures, along which slippage occurred during the initial stages of loading. Specimen No. 24 exhibited slight residual strain upon cycling.

Conclusions

5. The core received from hole P-CR-8 was quite variable, being described by the field log received with the core as amphibolite, greenish-black garnetiferous hornblende gneiss, white and red garnetiferous quartz gneiss, and amphibolite migmatite. All specimens contained fractures, some of which were inclined at critical angles and apparently caused substantial reductions in strength. The highly fractured specimens and those containing critical-angle fractures were highly incompetent, exhibiting an average compressive strength of 3345 psi. That rock containing high-angle or vertical fractures, however, was somewhat stronger, ranging in compressive strength from 10,000 to 17,000 psi. Compressive wave velocities were generally rather low, reflecting the many discontinuities present in this material.

Property	Highly and Critically Fractured Material	Material Containing Vertical Fractures
Specific Gravity	2.945	2.976
Schmidt Number	39.4	42.5
Compressive Strength, psi	3,345	14,025
Compressional Wave Velocity, fps	15,570	16,620
Static Young's Modulus, psi x 10^6	--	7.6

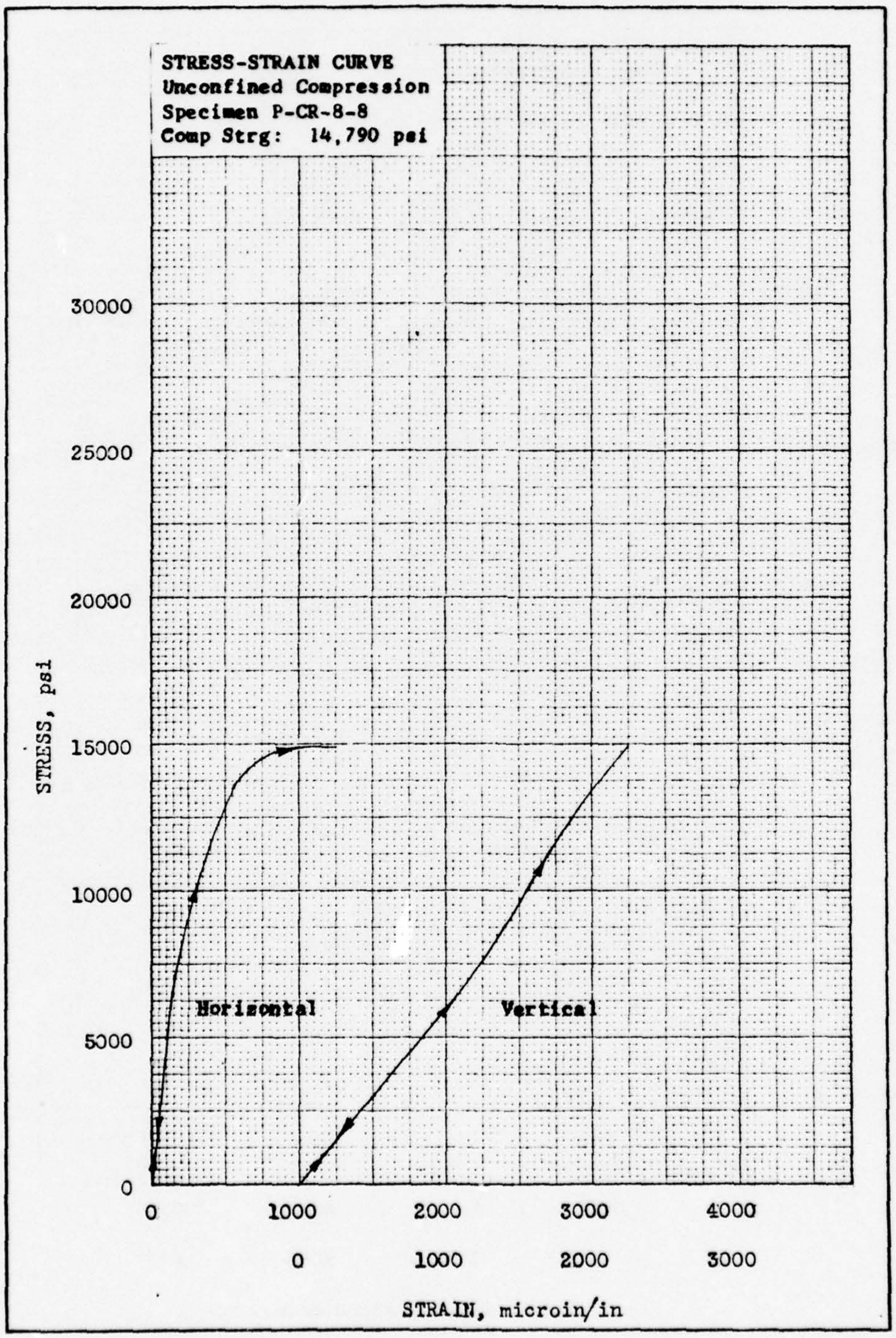
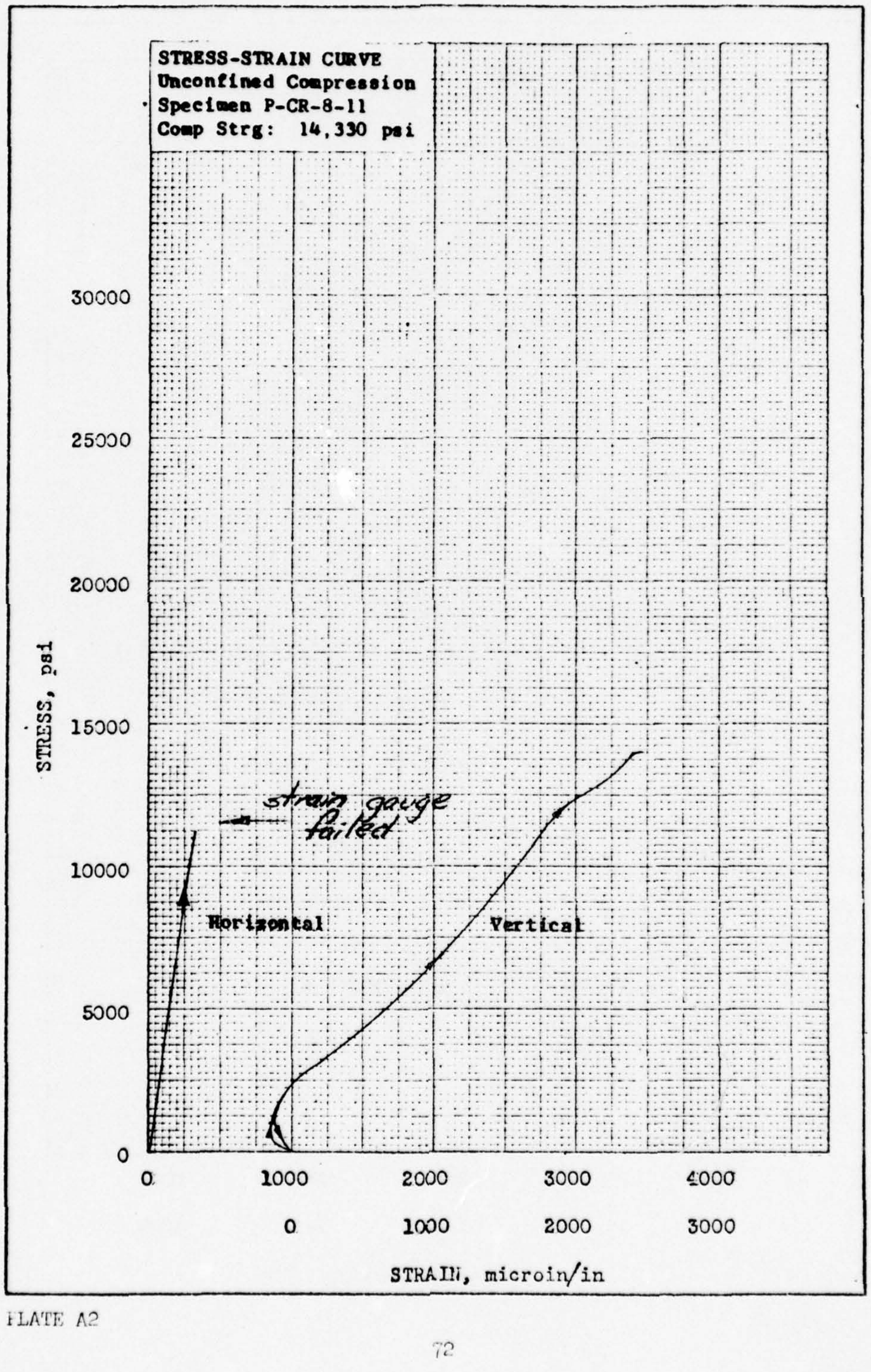

STRESS-STRAIN CURVE
Unconfined Compression
Specimen P-CR-8-8
Comp Strg: 14,790 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE A1



STRESS-STRAIN CURVE
Unconfined Compression
Specimen P-CR-8-11
Comp Strg: 14,330 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
strain gauge failed
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE A2

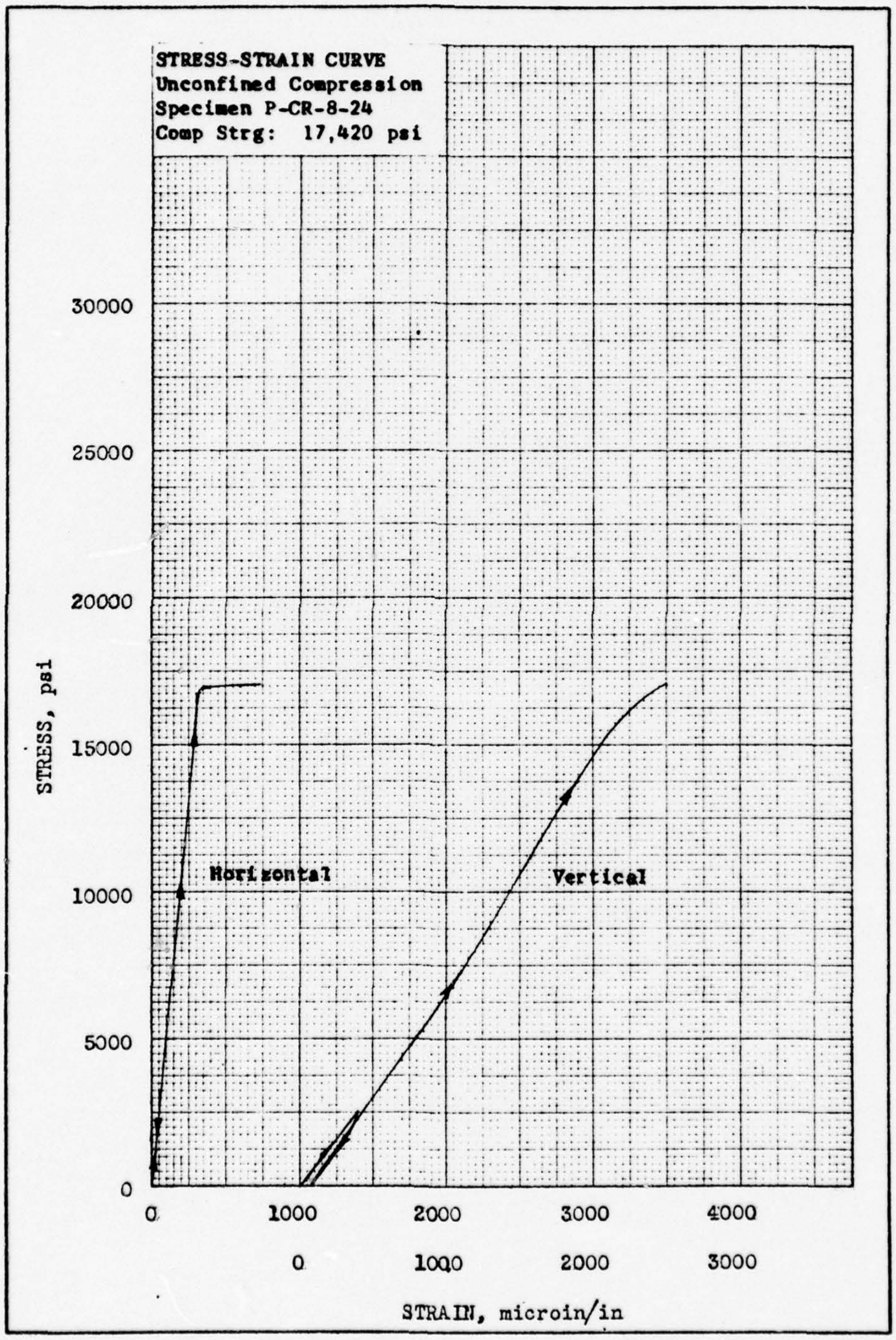

STRESS-STRAIN CURVE
Unconfined Compression
Specimen P-CR-8-24
Comp Strg: 17,420 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE A3

APPENDIX B

DATA REPORT

Hole P-CR-22

6 November 1969

Hole Location: Warren County, New York

Core

1. The following core was received on 14 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	10
2	20
3	33
4	39
5	50
6	55
7	64
8	70
9	81
10	90
11	101
12	109
13	116
14	127
15	131
16	136
17	147
18	156
19	168
20	177
21	186
22	197

Description

2. The samples received were somewhat variable in appearance. According to the field log received with the core, the rock was identified as light-gray to black gneiss. Specimen Nos. 9, 13, 15, and 19 contained fractures. Specimen No. 15 was highly fractured and, as a result, could not be prepared for testing.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps
2	Dark, Well-Banded Gneiss	20	2.994	45.2	15,000	15,480
4	Light Gray; Contained High-Angle Fracture	39	2.746	46.4	13,880	16,510
5	Light, Finely Banded Gneiss	50	2.713	43.0	14,640	11,390
6	Dark, Poorly Banded Gneiss	55	2.906	--	8,240	15,045
8	Inclusive Material	70	2.983	42.3	15,840	18,895
9	Mottled Inclusive Material	81	2.901	52.7	9,030	14,150
11	Black, Poorly Banded Gneiss	101	3.069	--	8,515	15,045
12	Dark, Poorly Banded Gneiss	109	2.953	43.7	10,270	13,060
16	Light, Well-Banded Gneiss	136	2.703	48.6	19,330	12,145
18	Dark; Contained Coarse Biotite Bands	156	2.913	41.1	9,020	10,655
20	Gray, Well-Banded Gneiss	177	2.737	43.4	21,545	13,125
22	Light, Coarsely Banded Gneiss	197	2.706	44.2	21,330	13,710
Average of Dark Gneiss (High Biotite Content) (5)			2.967	43.3	10,210	13,860
Average of Inclusive Materials (2)			2.942	47.5	12,435	16,520
Average of Light-Colored Gneiss (5)			2.721	45.1	18,145	13,375

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

4. The relatively low compressive velocities observed in this material generally fell well within the range noted by Professor S. P. Clark, Jr.,* i.e., 11,000 to 17,000 fps. The velocities tabulated by Clark were determined at low pressures (145 psi) with wave propagation normal to foliation. Velocities in this material were determined at zero pressure with wave propagation normal or nearly normal to foliation.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 9, 11, and 20. Stress-strain curves are given in plates 1, 2, and 3. Specimen 11 was cycled at 5000 psi and specimen 20 at 10,000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
9	6.1	4.0	2.4	8205	0.25
11	7.6	5.4	3.0	8515	0.26
20	5.5	3.4	2.2	7795	0.23

(Continued)

* Professor S. P. Clark, Jr., Handbook of Physical Constants, The Geological Society of America, Inc., New York, N. Y., 1966.

(Continued)

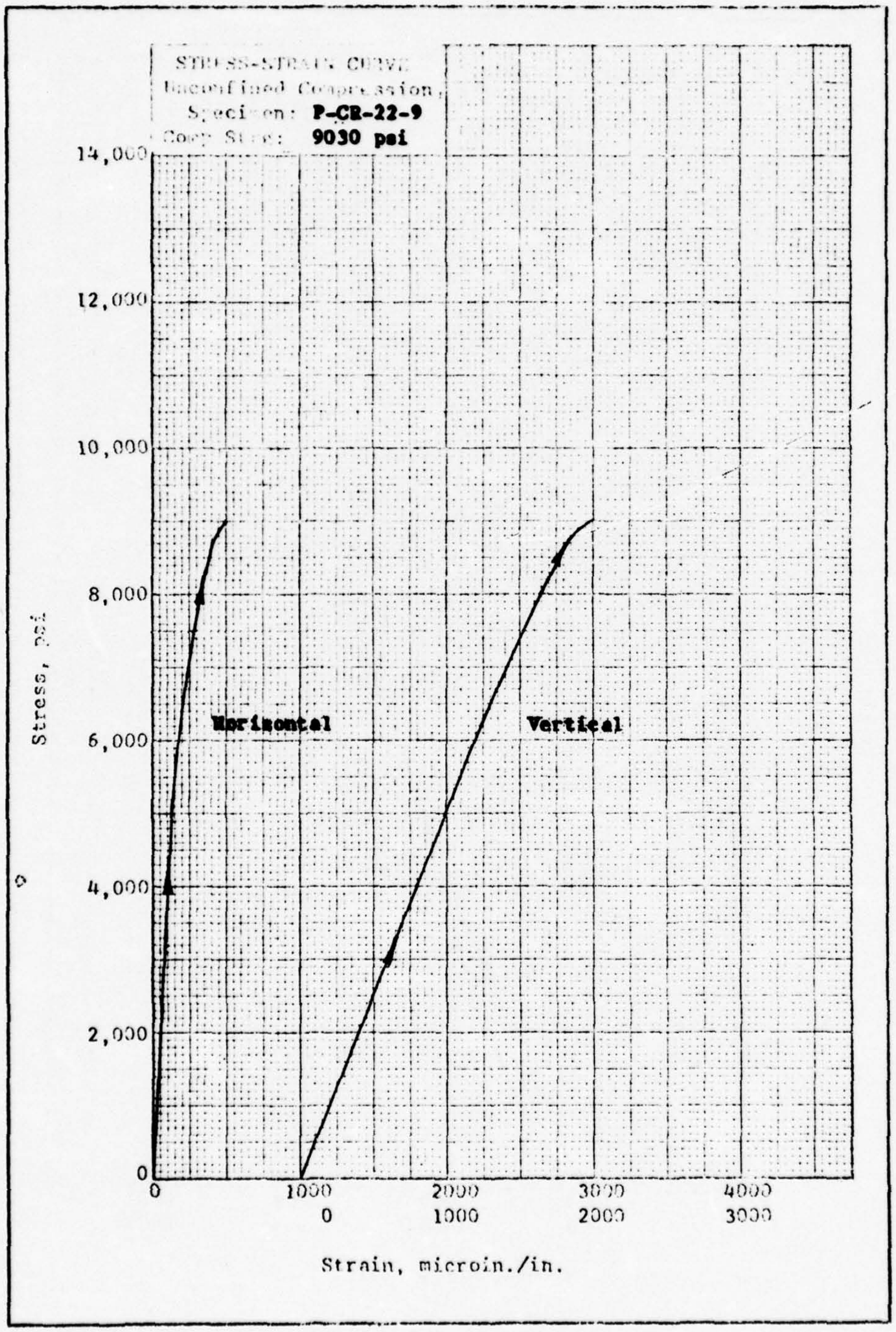
Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Static Tests			
9	5.0	2.1	2.2	--	0.14
11	5.7	2.3	2.7	--	0.08
20	8.0	3.9	3.5	--	0.16

All of the rock tested herein is apparently rather rigid material, exhibiting some hysteresis. Upon cycling, slight residual strain was detected in specimen No. 11.

Conclusions

6. The core received from hole P-CR-22 was somewhat variable in appearance, identified by the field log received with the core as light-gray to black gneiss. Specimen Nos. 9, 13, 15, and 19 contained fractures. The darker material was found to be considerably more dense and somewhat weaker than the remainder of the core from this hole, probably due to the abundance of biotite. The inclusive material was slightly stronger and less dense. The light-colored gneiss contained less biotite and was generally found to be considerably stronger, averaging approximately 18,000 psi in unconfined compressive strength. The weakest material tested was a dark, poorly banded gneiss which failed at 8240 psi. Compressive wave velocities ranged from 10,000 to 19,000 fps, agreeing rather well with data published on gneisses from this same general area.

Property	Inclusive Material	Dark Gneiss	Light Gneiss
Specific Gravity	2.942	2.967	2.721
Schmidt Number	47.5	43.3	45.1
Compressive Strength, psi	12,435	10,210	18,145
Compressional Wave Velocity, fps	16,520	13,860	13,375
Static Young's Modulus, psi x 10^6	5.0	5.7	8.0



STRESS-STRAIN CURVE
Unconfined Compression,
Specimen: P-CR-22-9
Comp Str: 9030 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE B1

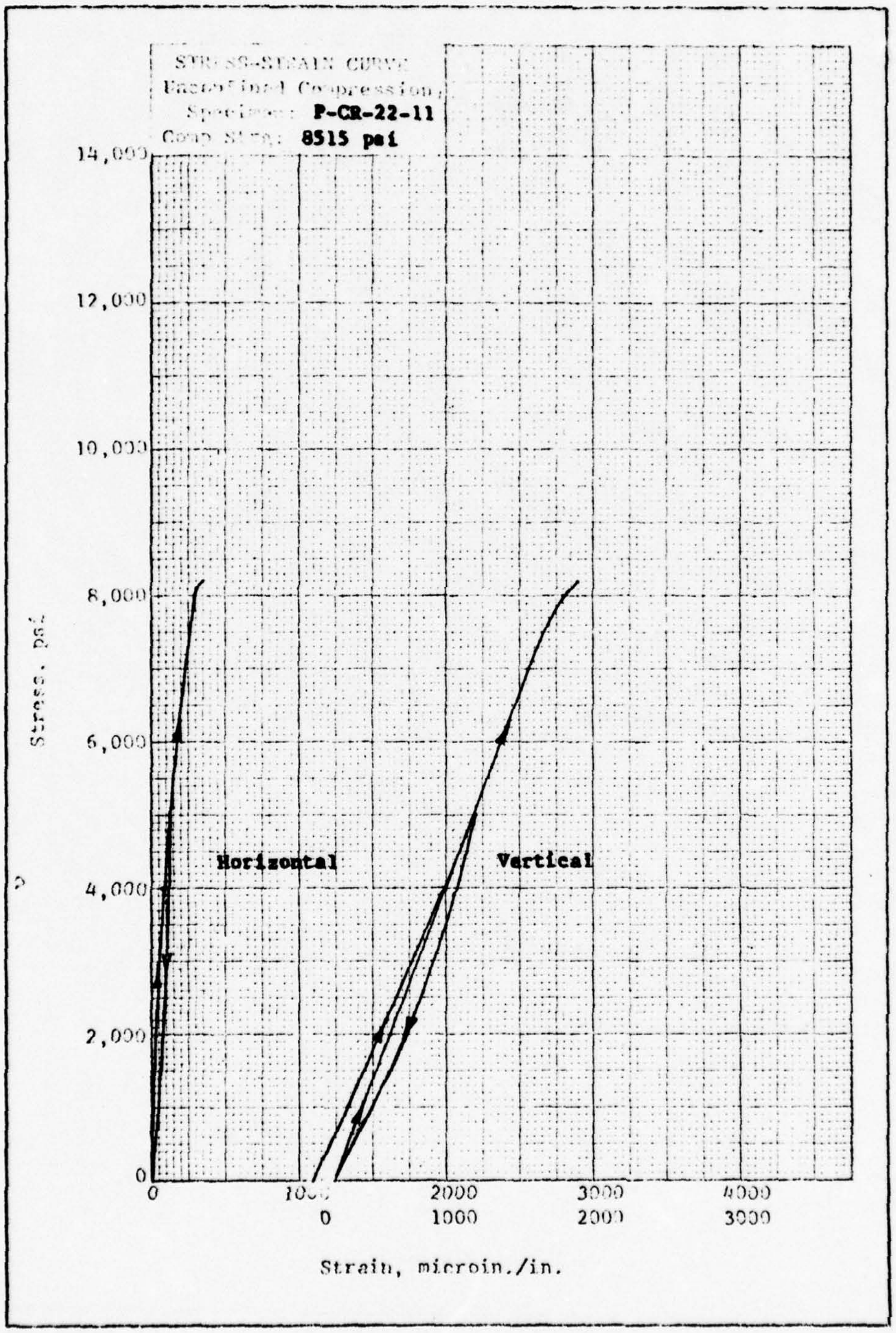

STRESS-STRAIN CURVE
Unconfined Compression,
Specimen: P-CR-22-11
Comp Str.: 8515 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE B2

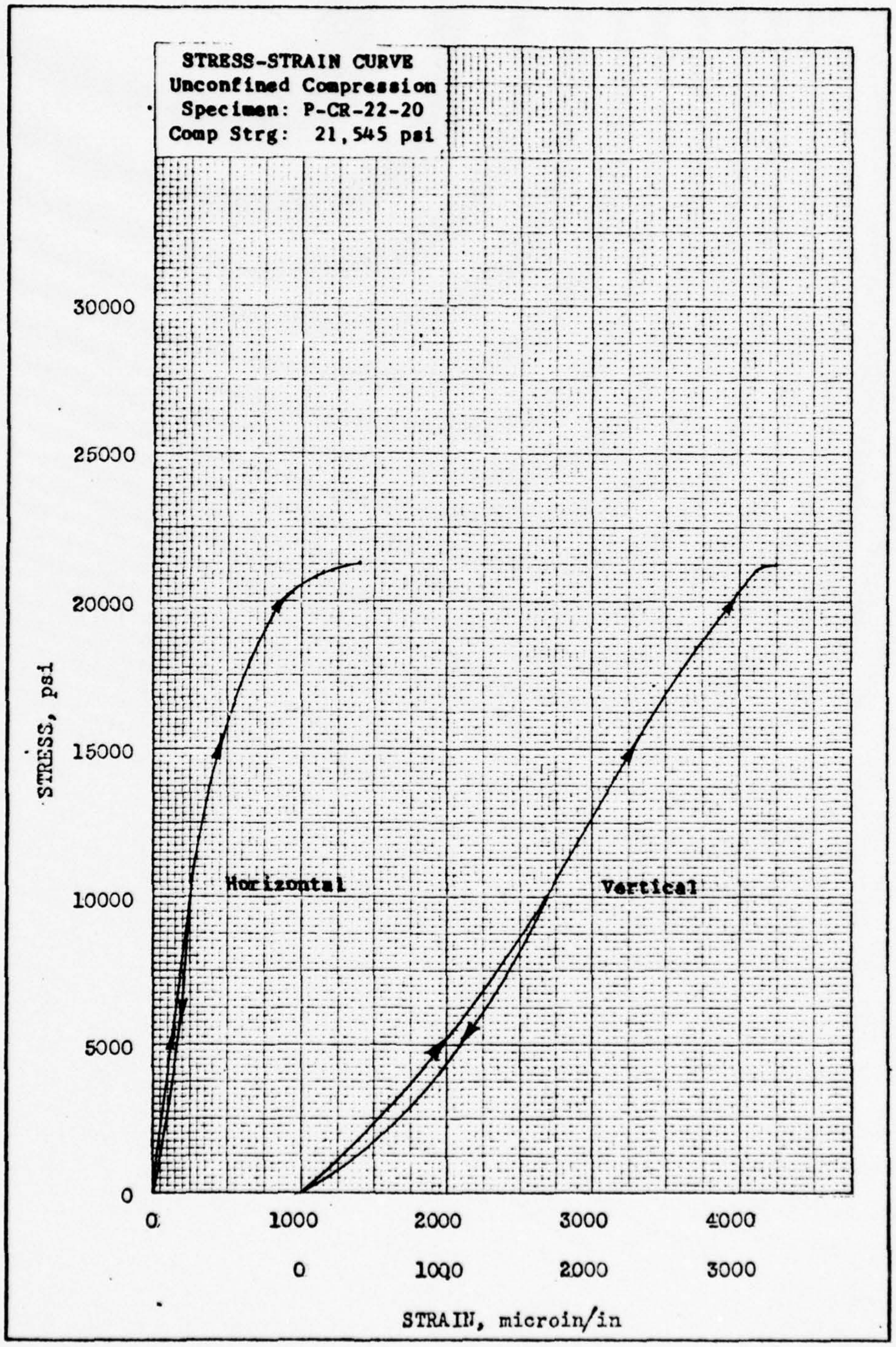

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: P-CR-22-20
Comp Strg: 21,545 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE B3

APPENDIX C

DATA REPORT

Hole P-CR-46

7 November 1969

Hole Location: Warren County, New York

Core

1. The following core was received on 21 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	41
2	49
3	54
4	60
5	66
6	71
7	81
8	88
9	96
10	105
11	114
12	124
13	131
14	137
15	143
16	153
17	162
18	171
19	180
20	187
21	195

Description

2. The samples received were rather uniform in appearance. According to the field log received with the core, the rock was identified as white to gray charnockitic gneiss generally with low-angle to horizontal lineation. Specimen Nos. 1, 2, 3, and 4 were somewhat weathered. Specimen Nos. 5, 7, 8, 10, 15, 18, 19, and 21 contained fractures, some of which were oriented at critical angles.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps
2	Moderately Weathered	49	2.647	34.7	12,545	15,560
7	Healed, Critical-Angle Fractures	81	2.667	48.5	4,985	15,110
8	Vertical Fractures	88	2.793	45.8	14,605	15,620
10	Healed, Critical-Angle Fractures	105	2.708	48.4	4,790	15,225
11	Disrupted Quartz Vein	114	2.709	45.6	8,575	14,780
15	Healed, Vertical Fractures	143	2.686	49.8	8,605	14,740
17	Healed, Critical-Angle Fractures	162	2.691	--	8,545	13,780
18	Healed, Critical-Angle Fractures	171	2.678	40.6	8,575	14,550
19	Healed, Vertical Fractures	180	2.704	--	16,180	15,575
21	Healed, Horizontal Fracture	195	2.691	--	13,970	14,935
Average of Specimens Containing Healed, Critical-Angle Fractures (4)			2.686	45.8	6,725	14,665
Average of All Other Specimens (6)			2.705	43.8	12,415	15,200

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

4. Specimen Nos. 7, 10, 17, and 18 contained critically oriented fractures, all of which were healed to various extents. Failure occurred along these fractures at relatively low stresses.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 7, 11, and 17. Stress-strain curves are given in plates 1, 2, and 3. Specimens 11 and 17 were cycled to 7500 psi. Results are given below.

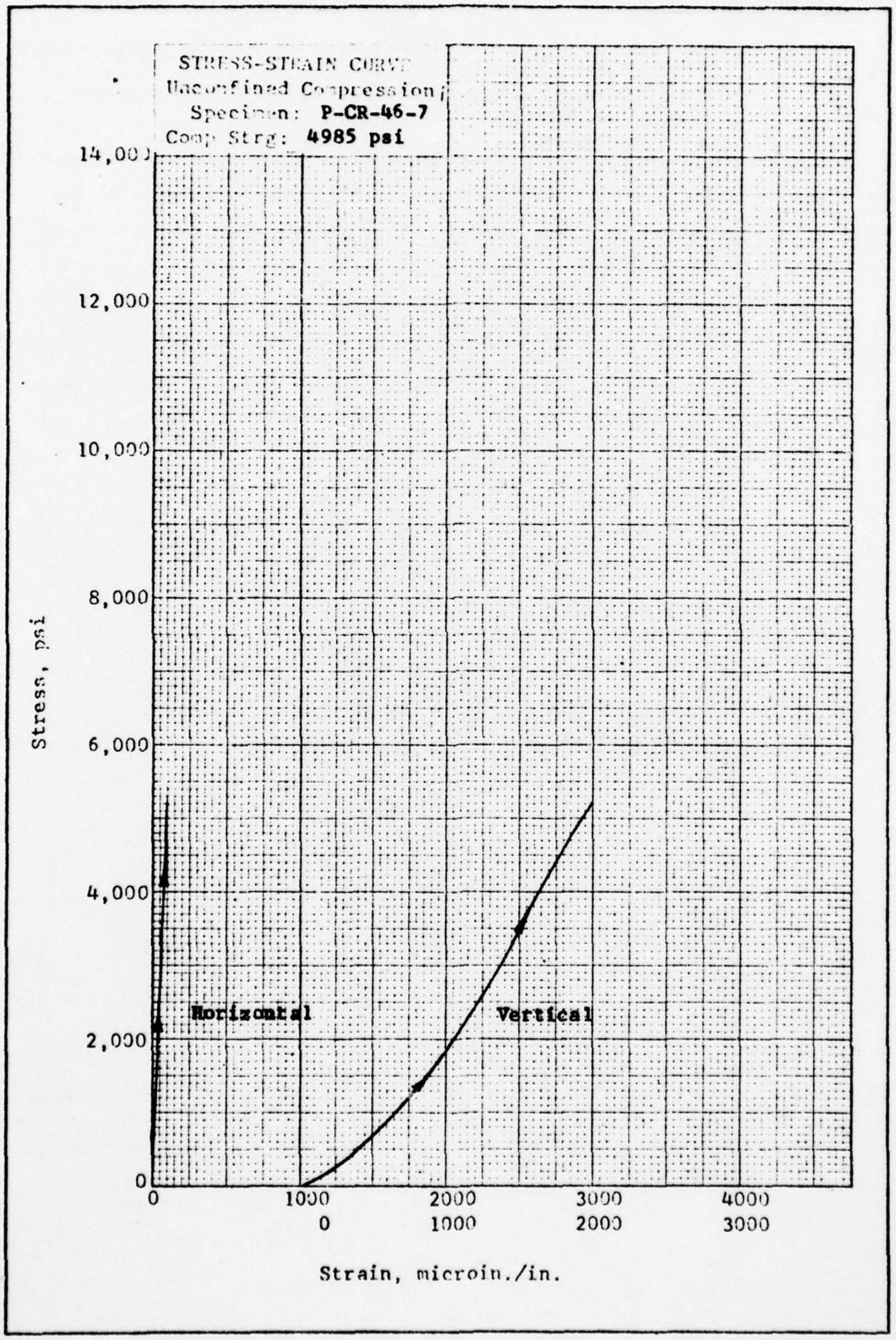
Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
7	6.8	4.6	2.7	8690	0.25
11	6.9	4.3	2.8	8740	0.23
17	6.5	3.1	2.8	8835	0.15
		Static Tests			
7	3.3	1.9	1.6	--	0.03
11	8.0	3.3	3.6	--	0.10
17	6.2	3.1	2.7	--	0.16

The specimens which were cycled, Nos. 11 and 17, exhibited substantial hysteresis and, upon unloading, considerable residual strain. The very low static moduli computed for specimen No. 7 were apparently the result of failure at low stress occurring along a poorly healed, critically inclined fracture.

Conclusions

6. The core received from hole P-CR-46 was generally uniform, identified by the field log received with the core as white to gray charnockitic gneiss. Lineation was primarily horizontal. Specimens 1, 2, 3, and 4 were somewhat weathered; specimens 5, 7, 8, 10, 15, 18, 19, and 21 contained fractures, most of which were healed, some critically oriented. The material containing critically oriented fractures was generally weaker than the remainder of the core, with failure occurring along the fractures at very low compressive stresses. The remainder of the core from this hole exhibited rather marginal strength values ranging from 8000 to 16,000 psi.

Property	Material Containing Critical-Angle Fractures	All Other Material
Specific Gravity	2.686	2.705
Schmidt Number	45.8	43.8
Compressive,Strength, psi	6,725	12,415
Compressional Wave Velocity, fps	14,665	15,220
Static Young's Modulus, psi x 10^6	4.8	8.0



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: P-CR-46-7
Comp Strg: 4985 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE C1

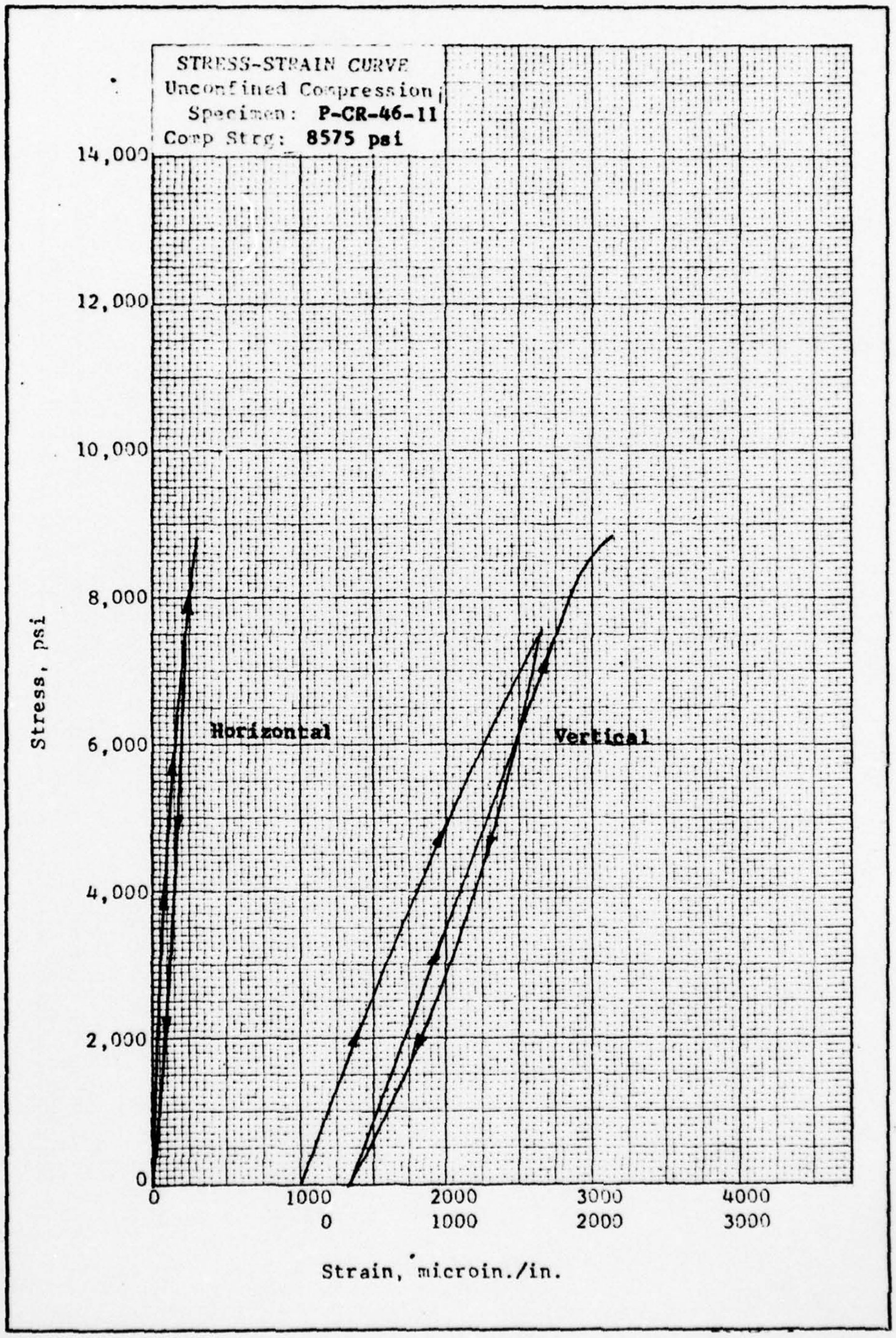
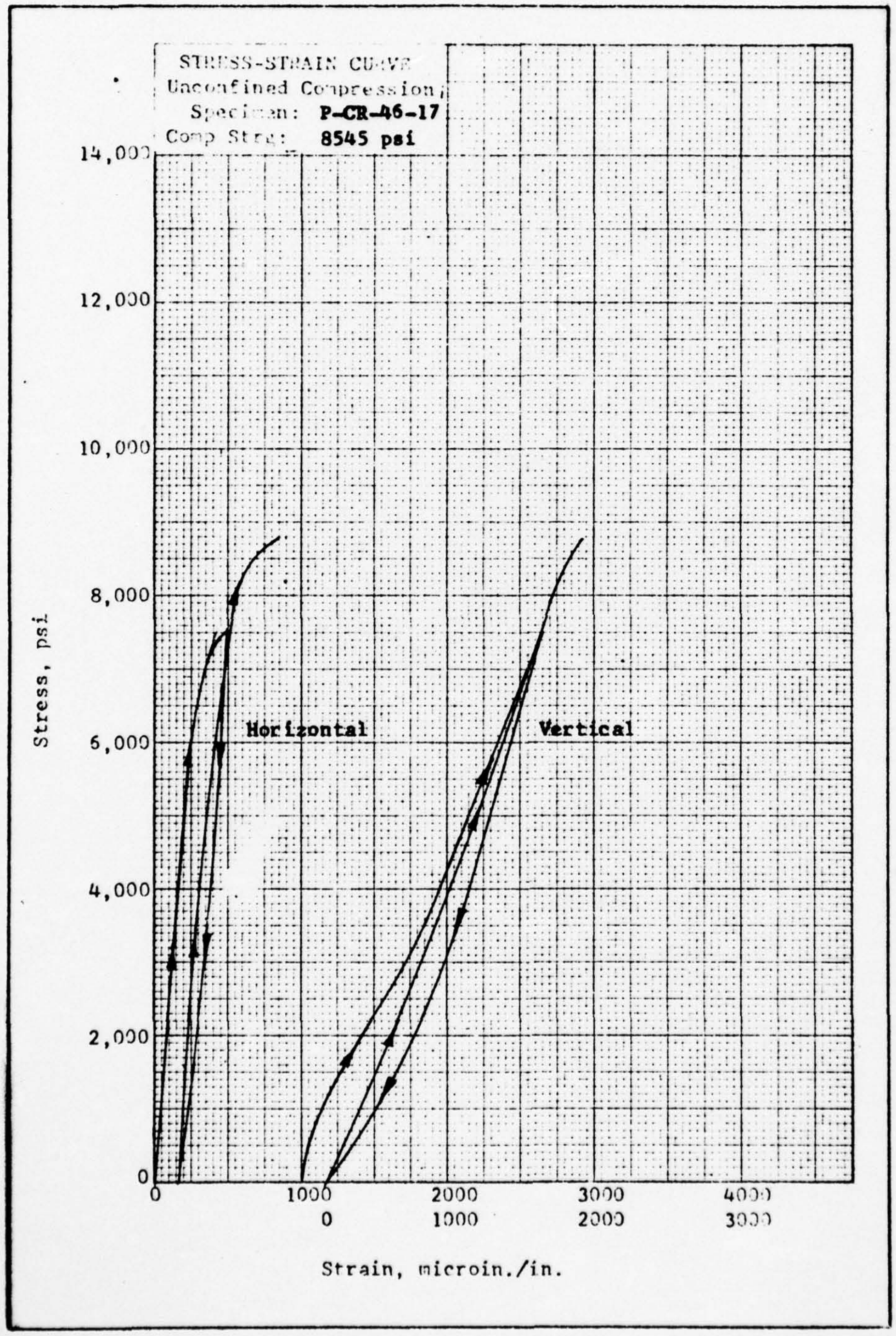

STRESS-STRAIN CURVE
Unconfined Compression
Specimen: P-CR-46-11
Comp Strg: 8575 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE C2



STRESS-STRAIN CURVE
Unconfined Compression
Specimen: P-CR-46-17
Comp Str: 8545 psi
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Stress, psi
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
Strain, microin./in.

PLATE C3

APPENDIX D

DATA REPORT

Hole P-CR-64

28 October 1969

Hole Location: Clinton County, New York

Core

1. The following core was received on 6 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	5
2	16
3	24
4	31
5	35
6	44
7	55
8	64
9*	62
10*	69
11*	71
12*	77
13*	86
14*	94
15*	104
16*	116
17*	125
18*	126
19*	137
20*	142
21*	145
22*	150
23*	157
24*	167
25*	175
26*	177
27*	187
28*	190
29*	200

* Specimens taken from side-tracked hole.

Description

2. The samples received were somewhat variable in appearance. According to the field log received with the core, the rock was identified as

medium- to coarse-grained, gray to yellow-brown quartzite. Zones of limonite staining were present throughout the core. Specimen Nos. 4, 8, 10, 11, and 18 contained incipient fractures. Specimens from the lower reaches of the hole were increasingly conglomeritic.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Core Log Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps
2	Intact Quartzite	16	2.645	47.4	31,670	9,765
4	Contained Incipient Fracture	31	2.633	--	21,760	11,810
6	Intact Quartzite	44	2.697	--	30,450	14,010
8	Contained Incipient Fracture	64	2.622	45.9	30,910	11,305
10	Contained Incipient Fracture	69	2.631	50.6	25,300	12,255
14	Transitional Material	94	2.592	50.7	17,420	10,985
16	Conglomeritic Quartzite	116	2.600	--	18,940	10,615
18	Conglomeritic Quartzite	126	2.585	--	17,080	10,535
21	Conglomeritic Quartzite	145	2.573	--	12,210	8,655
27	Conglomeritic Quartzite	187	2.532	44.3	15,520	9,655
Average of Nonconglomeritic Material (5)			2.645	48.0	28,020	11,830
Average of Conglomeritic and Transitional Material (5)			2.576	47.5	16,230	10,090

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

4. Compressive wave velocities exhibited by the material from hole P-CR-64 were comparatively low, particularly for the quartzite. Preliminary examination by stereomicroscope (to be followed at a later date by thorough petrographic analysis) indicated that the material was sandstone rather than quartzite as reported in the core log. Compressive velocities of 7000 to 14,000 fps* are not uncommon for sandstone.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. Dynamic properties of specimen No. 27 could not be reliably determined due to the unusually large shear velocity to compressive velocity ratio exhibited by the specimen. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos 4 and 27. Stress-strain curves are given in plates 1 and 2. Both specimens were cycled at 10,000 psi. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
4	4.9	1.9	2.3	8005	0.07
27	--	--	--	--	--

(Continued)

* Professor S. P. Clark, Jr., Handbook of Physical Constants, The Geological Society of America, Inc., New York, N. Y., 1966.

(Continued)

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
			Static Tests		
4	6.7	2.8	3.0	--	0.10
27	5.0	1.9	2.2	--	0.12

All of the rock tested herein is apparently rather rigid material, exhibiting substantial hysteresis. However, little residual strain was detected.

Conclusions

6. The core received from hole P-CR-64 was somewhat variable, being described by the field log received with the core as medium- to coarse-grained, gray to yellow-brown quartzite. Several specimens contained incipient fractures which appeared to have little effect on compressive strength. Specimens from the lower reaches of the hole were increasingly conglomeritic and predictably weaker, exhibiting an average compressive strength of slightly more than 50 percent of that yielded by the nonconglomeritic rock. In spite of the greater weakness observed in the conglomeritic material, the minimum compressive strength observed was 12,000 psi.

Property	Conglomeritic Material	Nonconglomeritic Material
Specific Gravity	2.576	2.646
Schmidt Number	47.5	48.0
Compressive Strength, psi	16,230	28,020
Compressional Wave Velocity, fps	10,090	11,830
Static Young's Modulus, psi x 10^6	0.12	0.10

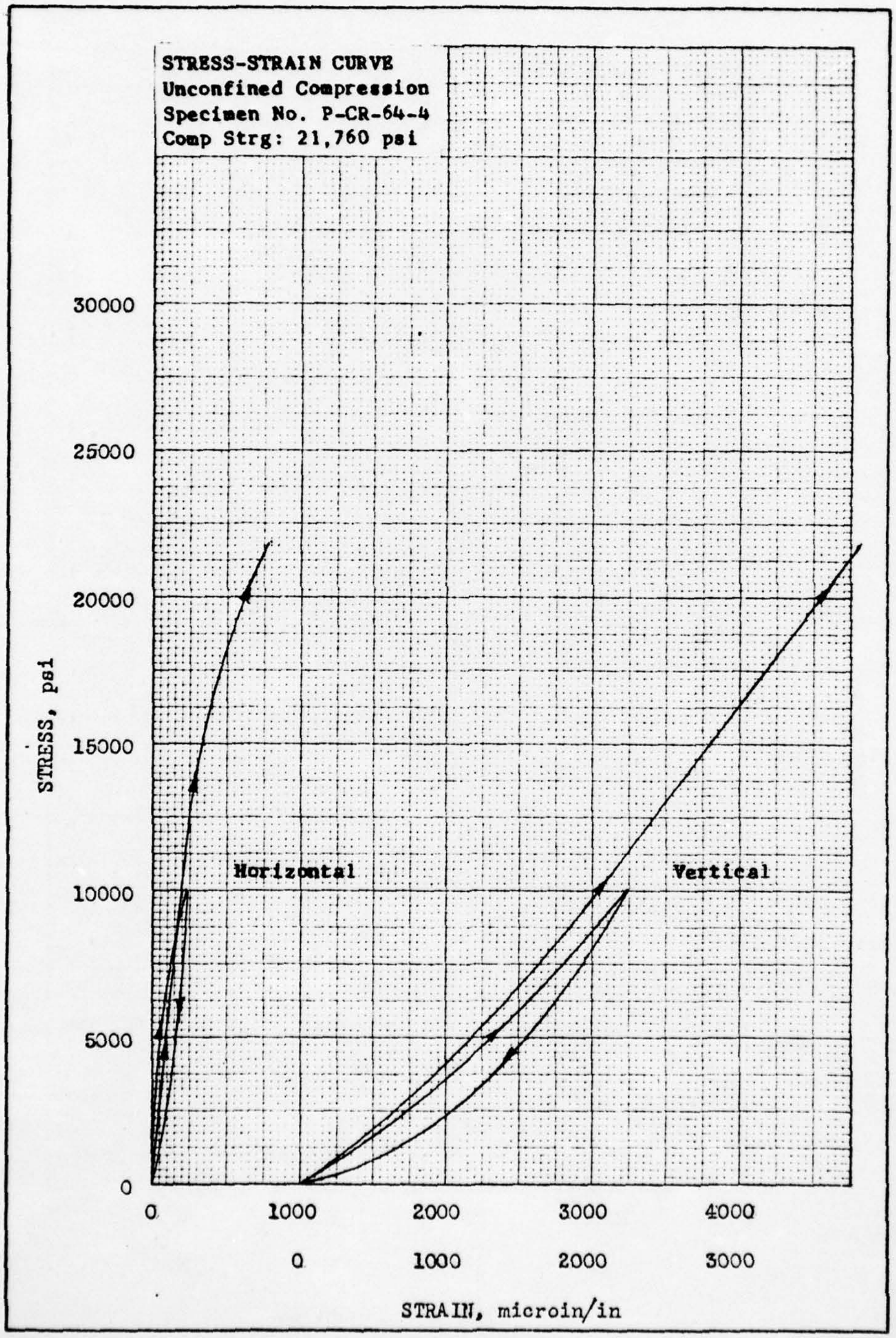
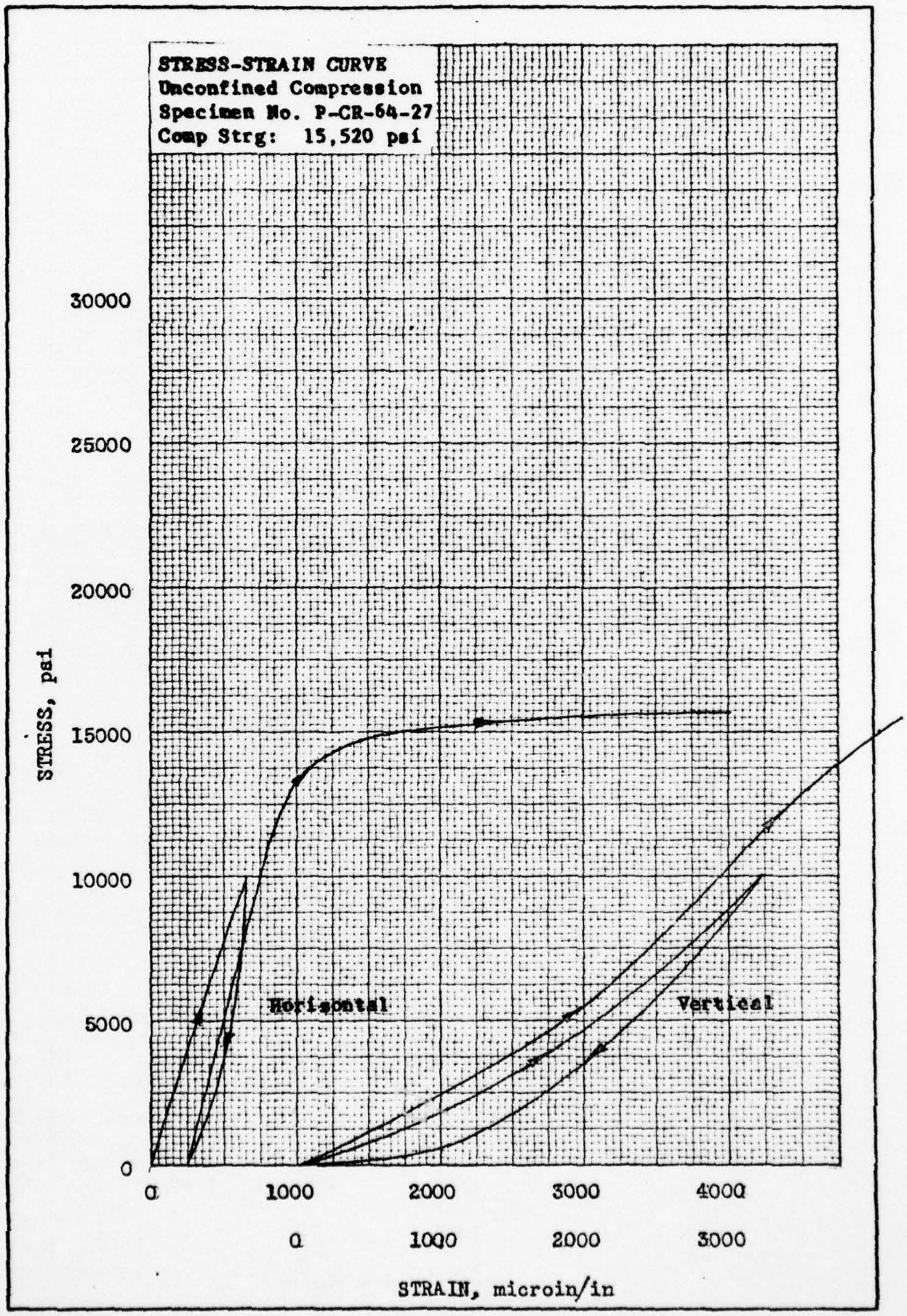

STRESS-STRAIN CURVE
Unconfined Compression
Specimen No. P-CR-64-4
Comp Strg: 21,760 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE D1



STRESS-STRAIN CURVE
Unconfined Compression
Specimen No. P-CR-64-27
Comp Strg: 15,520 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE D2

APPENDIX E

DATA REPORT

Hole P-CR-72

29 October 1969

Hole Location: Clinton County, New York

Core

1. The following core was received on 1 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	34
2	42
3	53
4	63
5	74
6	82
7	93
8	103
9	113
10	123
11	133
12	141
13	150
14	159
15	166
16	169
17	174
18	184
19	195
20	200

Description

2. The samples received were somewhat variable in appearance. According to the field log received with the core, the rock was identified as light- to dark-gray, fine- to medium-grained sandstone. Specimen Nos. 4, 6, and 20 contained tightly closed fractures.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Description	Core Depth	Sp Gr	Schmidt No.*	Comp Strg, psi	Comp Wave Vel, fps
1	Fine Grained	34	2.631	--	24,700	8,010
2	Fine Grained	42	2.596	45.7	30,000	9,190
4	Fine Grained	63	2.550	49.9	34,700	9,190
6	Fine Grained	82	2.510	54.0	22,050	12,060
9	Medium Grained	113	2.585	49.5	25,610	13,030
10	Medium Grained	123	2.525	47.8	15,920	9,180
12	Medium Grained	141	2.494	48.8	13,830	8,530
14	Medium Grained	159	2.587	47.5	19,700	10,230
17	Medium Grained	174	2.613	--	17,000	9,790
18	Fine Grained	184	2.545	--	15,210	8,620
20	Medium Grained	200	2.519	--	13,030	7,570
Average of Fine-Grained Specimens (5)			2.566	49.9	25,330	9,410
Average of Medium-Grained Specimens (6)			2.554	48.4	17,520	9,720

* Schmidt hammer test not conducted on several specimens due to possibility of breakage.

4. Compressive wave velocities exhibited by the material from hole P-CR-72 were very low, averaging approximately 10,000 fps. These

AD-A035 372 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 8/7
TESTS OF ROCK CORES, PLATTSBURGH STUDY AREA, NEW YORK.(U)
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UNCLASSIFIED WES-MP-C-70-7 NL

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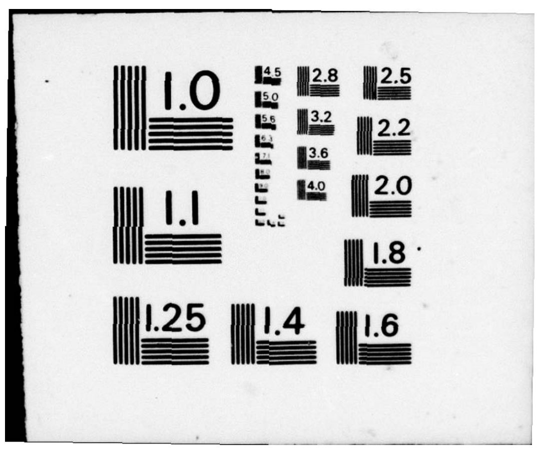

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0

low velocities were, however, quite representative of this type of material, generally having been found to range from 7000 to 14,000 fps.*

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. Due to the unrealistically high shear velocity to compressive velocity ratios observed in this material, dynamic constants could not be accurately determined. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 2, 4, and 14. Stress-strain curves are given in plates 1, 2, and 3. All specimens were cycled at 10,000 psi. Results are given below.

Specimen	Modulus, psi x 10^6			Shear	Poisson's
No.	Young's	Bulk	Shear	Velocity, fps	Ratio
			Dynamic Tests		
2	--	--	--	--	--
4	--	--	--	--	--
14	--	--	--	--	--
			Static Tests		
2	5.9	2.3	2.8	--	0.07
4	6.8	3.0	3.0	--	0.12
14	5.1	2.2	2.8	--	0.12

All of the rock tested herein is apparently rather rigid material, exhibiting slight hysteresis. The stress-strain curves exhibited some reverse curvature indicative of initial crack closure.

* Professor S. P. Clark, Jr., Handbook of Physical Constants, The Geological Society of America, Inc., New York, New York, 1966.

Conclusions

6. The core received from hole P-CR-72 was somewhat variable in appearance, identified by the field log received with the core as light- to dark-gray, fine- to medium-grained sandstone. Physical properties of the material were noticeably dependent on grain size, the fine-grained rock being slightly more dense and decidedly stronger than the medium-grained material. The medium-grained material was still, however, relatively competent rock, the lowest uniaxial compressive strength observed being 13,000 psi. Compressive wave velocities were very low, a characteristic typical of sandstone in general.

Property	Fine-Grained Material	Medium-Grained Material
Specific Gravity	2.566	2.554
Schmidt Number	49.9	48.4
Compressive Strength, psi	25,330	17,520
Compressional Wave Velocity, fps	9,410	9,720
Static Young's Modulus, psi x 10^6	6.4	5.1

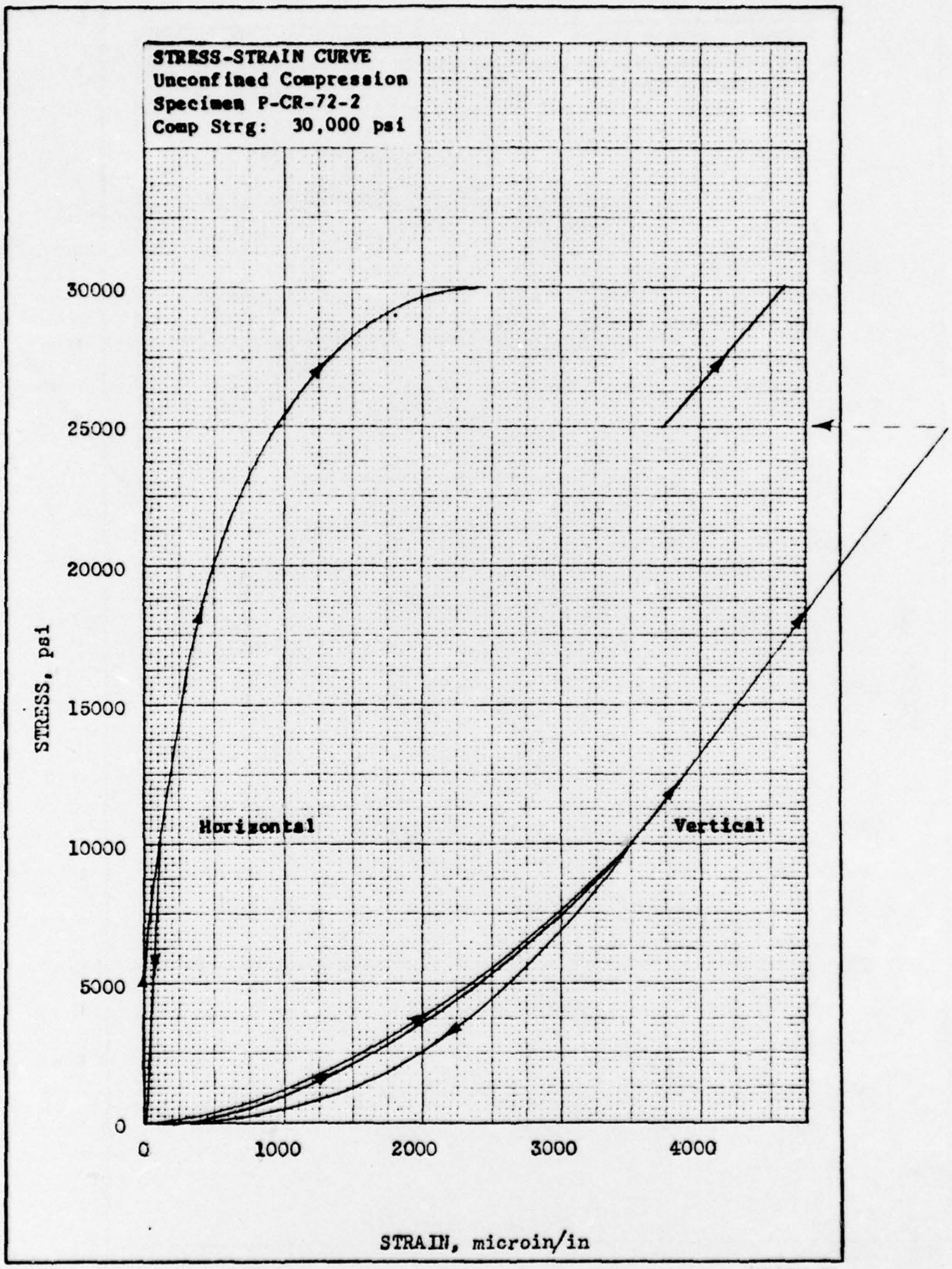

STRESS-STRAIN CURVE
Unconfined Compression
Specimen P-CR-72-2
Comp Strg: 30,000 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
STRAIN, microin/in

PLATE E1

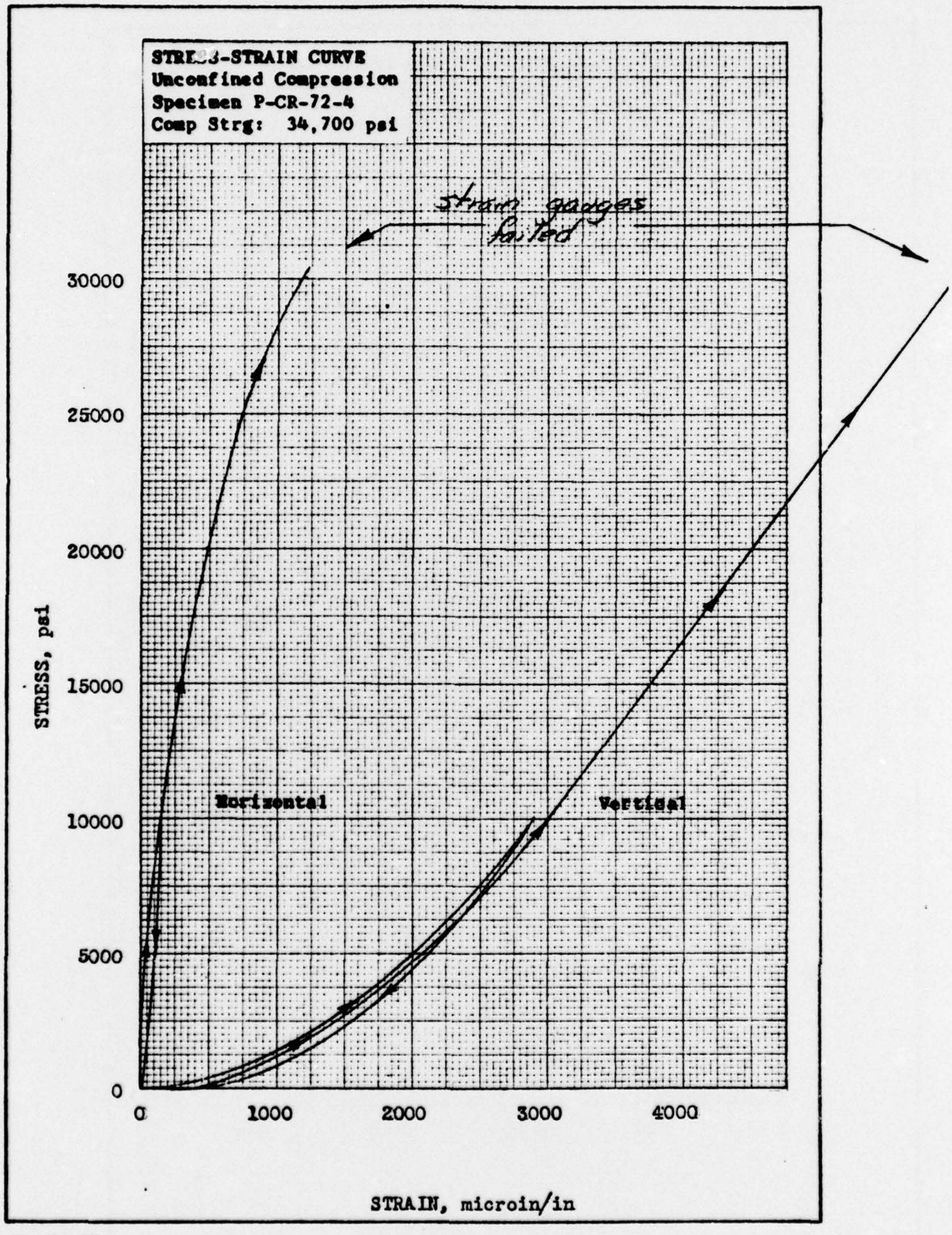
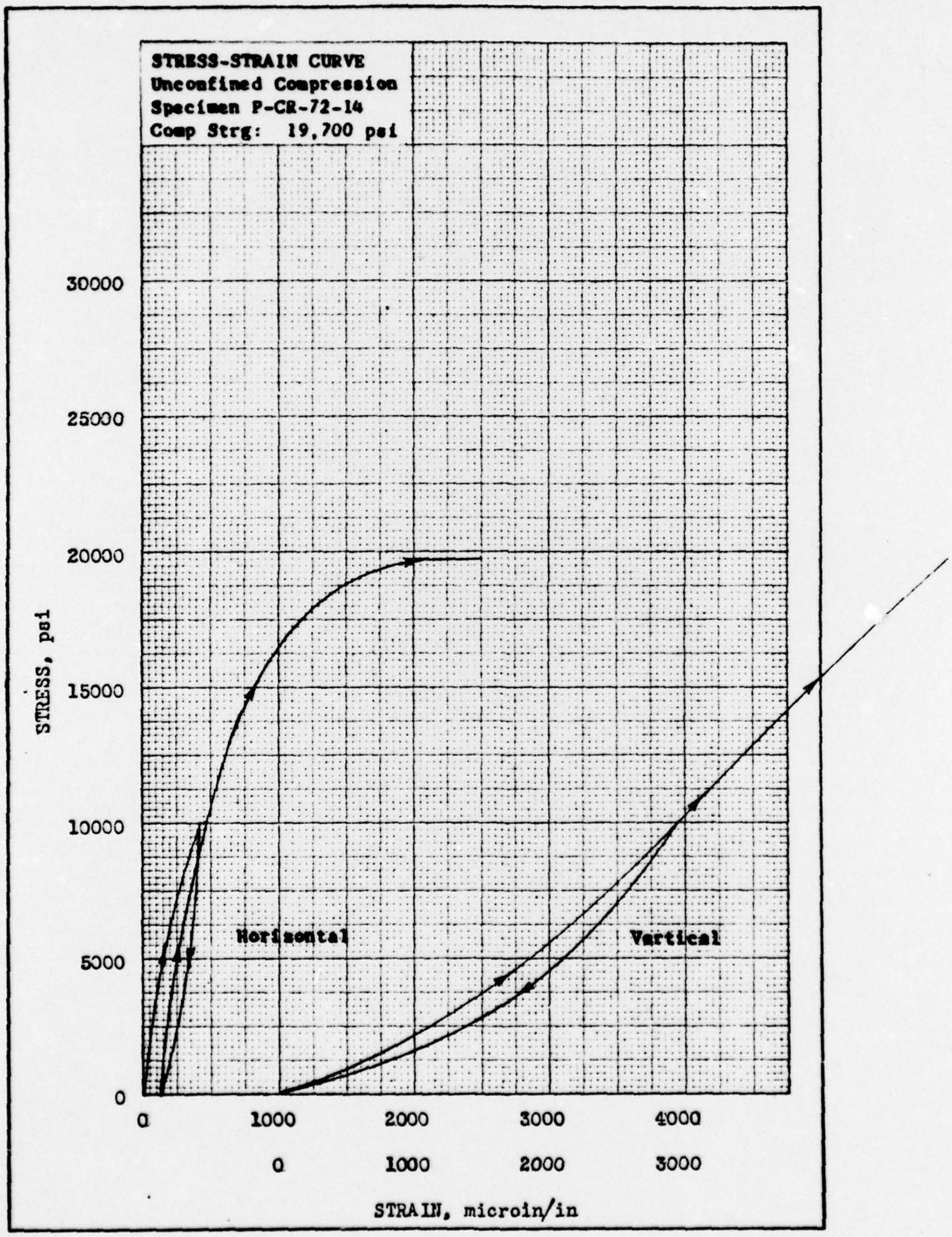

STRESS-STRAIN CURVE
Unconfined Compression
Specimen P-CR-72-4
Comp Strg: 34,700 psi
strain gauges failed
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
0
1000
2000
3000
4000
STRAIN, microin/in

PLATE E2



STRESS-STRAIN CURVE
Unconfined Compression
Specimen P-CR-72-14
Comp Strg: 19,700 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE E3

APPENDIX F

DATA REPORT

Hole P-CR-81

28 October 1969

Hole Location: Franklin County, New York

Core

1. The following core was received on 6 October 1969 for testing:

Core Piece No.	Approximate Depth, ft
1	8
2	16
3	27
4	38
5	46
6	56
7	66
8	74
9	84
10	93
11	94
12	103
13	114
14	123
15	124
16	129
17	140
18	150
19	158
20	167
21	175
22	177
23	187
24	199

Description

2. The samples received were somewhat variable in appearance. According to the field log received with the core, the rock was identified as reddish-gray to gray granitic gneiss and chloritic hornblende gneiss. Specimen Nos. 4, 8, 10, 11, 15, 18, 20, and 21 contained incipient fractures, most of which were healed.

Quality and uniformity tests

3. To determine variations within the hole, specific gravity, Schmidt number, compressive strength, and compressional wave velocity were determined on specimens prepared from representative samples as given below:

Sample No.	Core Log Description	Core Depth	Sp Gr	Schmidt No.	Comp Strg, psi	Comp Wave Vel, fps
3	Intact Gneiss	27	2.734	58.1	27,300	17,685
7	Intact Gneiss	66	2.729	51.3	26,360	16,985
10	Vertical Healed Fracture	93	2.634	--	20,760	13,900
11	Healed Incipient Fracture	94	2.684	--	30,610	14,290
14	Intact Gneiss	123	2.694	--	20,760	16,190
15	Intrusive Material	124	2.959	45.2	27,970	16,840
17	Intact Gneiss	140	2.768	--	22,090	19,440
18	High-Angle Healed Joint	150	2.746	44.9	9,520	16,150
19	Intact Gneiss	158	3.076	42.7	21,420	20,490
20	Vertical Healed Joint	167	2.919	42.8	8,760	20,300
21	Healed Incipient Fracture	175	2.864	44.9	24,360	19,700
Average of Specimens with Healed Joints (2)			2.832	43.8	9,140	18,225
Average of Intact Specimens and Specimens with Healed Fractures (9)			2.794	48.4	24,630	17,280

4. The Schmidt hammer test was not conducted on several specimens due to possibility of breakage. Fractures are defined herein as irregular breaks and joints as relatively plane broken surfaces. Compressive wave velocities exhibited by the material from this hole were quite variable, possibly due to the presence of frequent garnet concentrations rather than general incompetence of the gneiss itself.

Moduli of deformation

5. Representative specimens were selected for dynamic and static moduli of deformation tests. The dynamic moduli were determined by the proposed ASTM method for determination of ultrasonic pulse velocities and elastic constants of rock. The static moduli were computed from theory of elasticity by use of strain measurements taken from electrical resistance strain gages affixed to the specimens, Nos. 3, 15, and 21. Stress-strain curves are given in plates 1, 2, and 3. All specimens were cycled at 10,000 psi. Static moduli for specimens 3 and 15 were computed at 50 percent of ultimate strength. Static moduli for specimen 21 were, due to erratic behavior of the horizontal strain gages, computed at 30 percent of ultimate strength. Results are given below.

Specimen No.	Modulus, psi x 10^6 Young's	Bulk	Shear	Shear Velocity, fps	Poisson's Ratio
		Dynamic Tests			
3	8.8	6.9	3.4	9660	0.29
15	9.6	6.1	3.9	9860	0.24
21	10.2	9.8	3.8	9990	0.33
		Static Tests			
3	8.5	5.7	3.4	--	0.25
15	12.2	8.4	4.8	--	0.26
21	9.1	5.7	3.7	--	0.24

All of the rock tested herein is apparently rather rigid material, exhibiting little hysteresis.

Conclusions

6. The core received from hole P-CR-81 was somewhat variable, identified by the field log received with the core as reddish-gray to gray granitic gneiss and chloritic hornblende gneiss. Several specimens contained healed, incipient fractures; two contained healed joints. The presence of healed, incipient fractures appeared to have no effect on uniaxial compressive strength; the intact and fractured material exhibited an average compressive strength of 24,630 psi. The material containing healed joints was found to be considerably weaker than the remainder of the rock, possibly due to the angle of inclination and the planeness of the joints.

Property	Specimens Containing Joints	Intact Specimens and Specimens with Healed Fractures
Specific Gravity	2.832	2.794
Schmidt Number	43.8	48.4
Compressive Strength, psi	9,140	24,630
Compressional Wave Velocity, fps	18,225	17,280
Static Young's Modulus, psi x 10^6	9.1	10.4

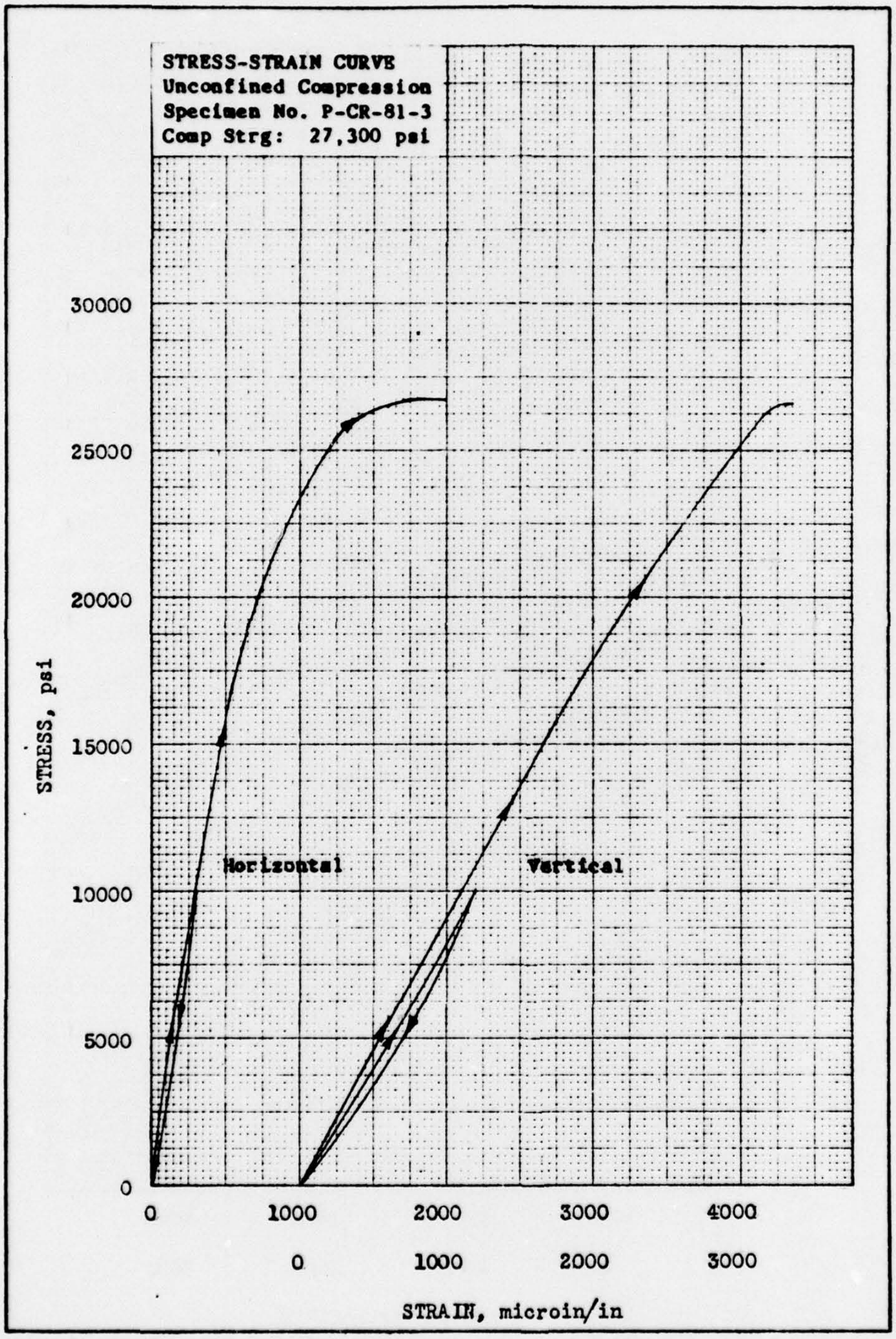

STRESS-STRAIN CURVE
Unconfined Compression
Specimen No. P-CR-81-3
Comp Strg: 27,300 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE F1

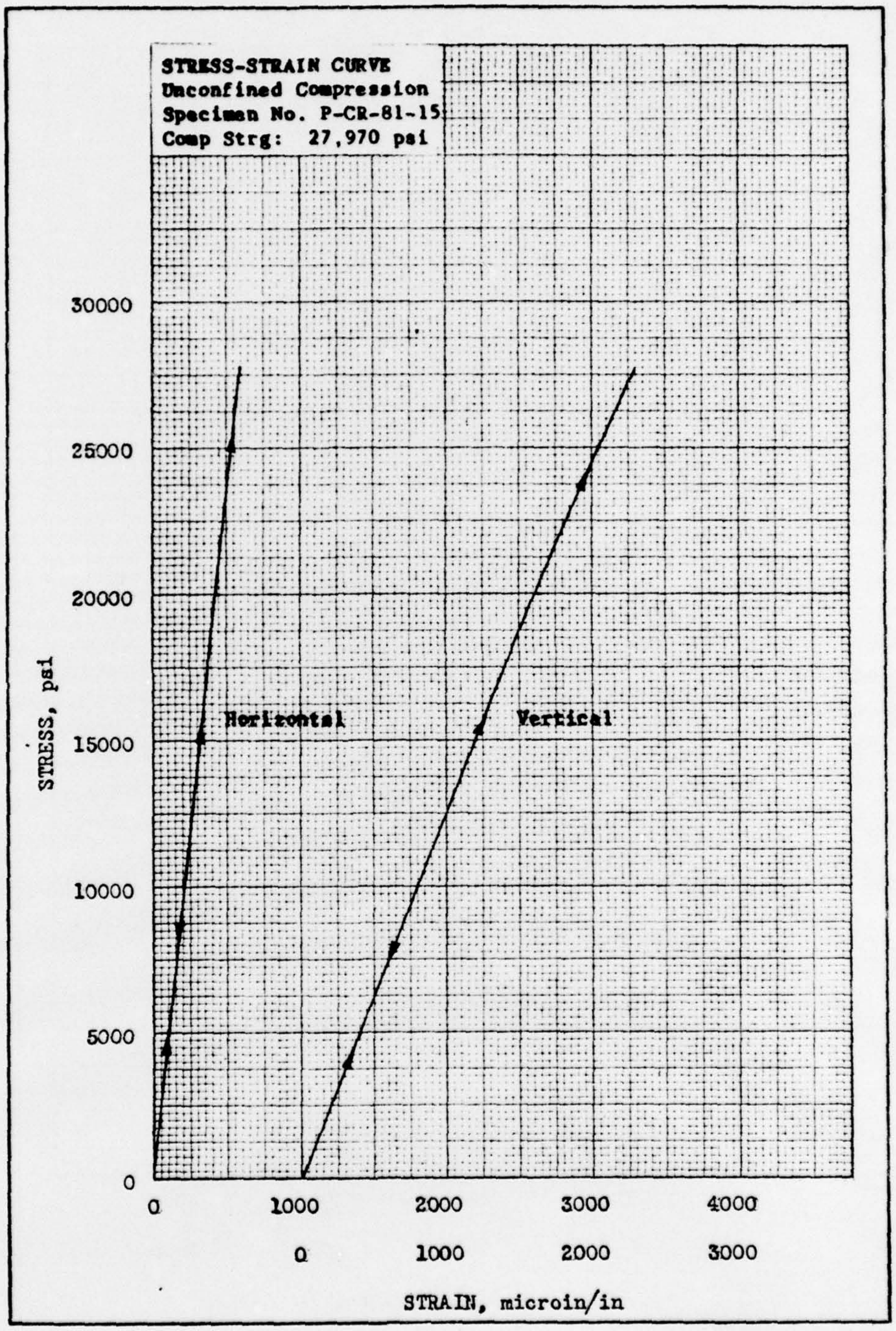

STRESS-STRAIN CURVE
Unconfined Compression
Specimen No. P-CR-81-15
Comp Strg: 27,970 psi
STRESS, psi
30000
25000
20000
15000
10000
5000
0
Horizontal
Vertical
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE F2

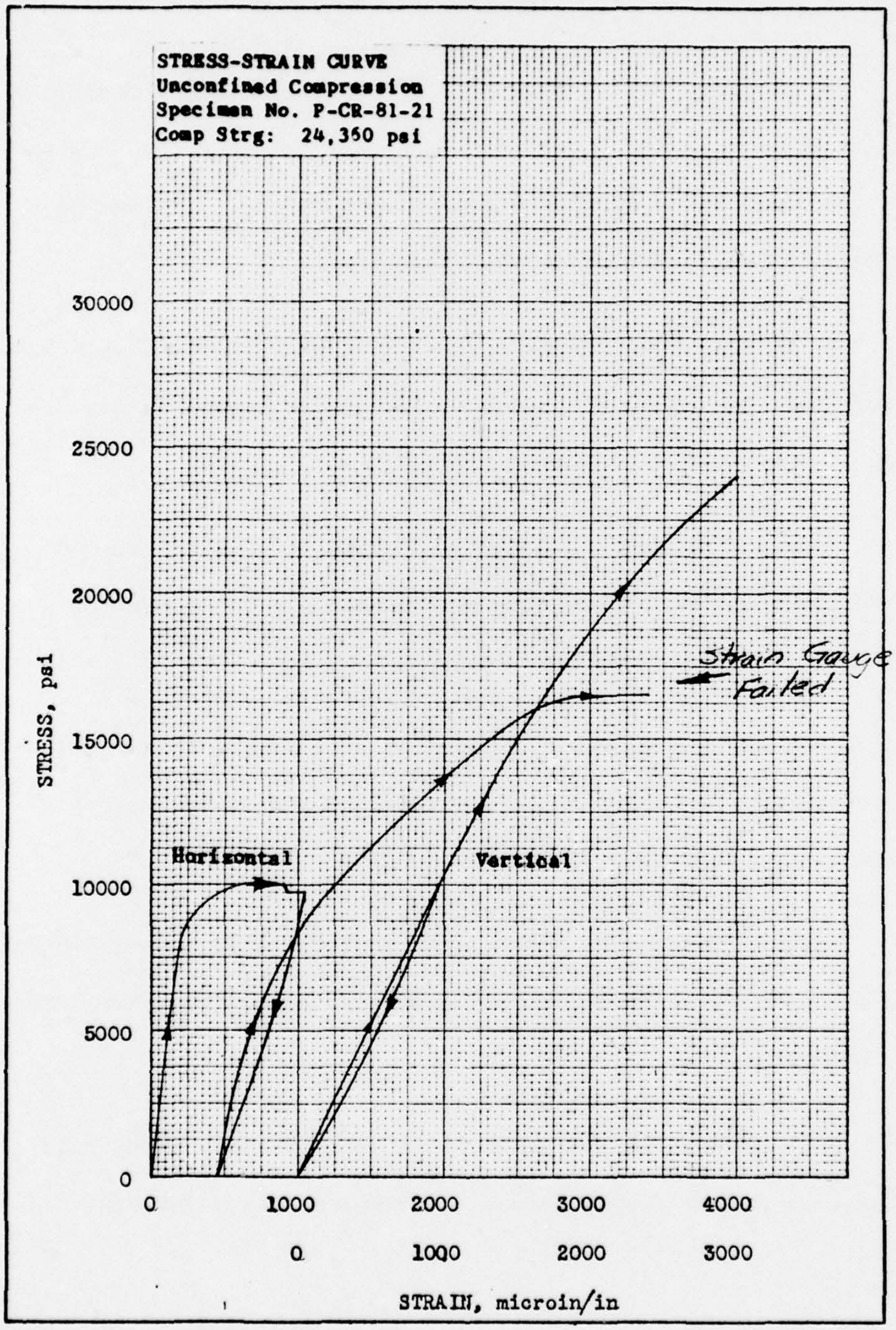

STRESS-STRAIN CURVE
Unconfined Compression
Specimen No. P-CR-81-21
Comp Strg: 24,360 psi
30000
25000
20000
15000
10000
5000
0
STRESS, psi
Horizontal
Vertical
Strain Gauge
Failed
0
1000
2000
3000
4000
0
1000
2000
3000
STRAIN, microin/in

PLATE F3

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1. ORIGINATING ACTIVITY (Corporate author) U. S. Army Engineer Waterways Experiment Station Vicksburg, Miss.	2a. REPORT SECURITY CLASSIFICATION Unclassified
	2b. GROUP
3. REPORT TITLE TESTS OF ROCK CORES, PLATTSBURGH STUDY AREA, NEW YORK .	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Final report, Oct - Nov 69	
5. AUTHOR(S) (First name, middle initial, last name) Robert W. Crisp	12 112p.
6. REPORT DATE June 1970	7a. TOTAL NO. OF PAGES 110 / 7b. NO. OF REFS 6
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) Miscellaneous Paper C-70-7
b. PROJECT NO. WES-MP-C-70-7	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
10. Approved for Public Release; Distribution Unlimited	have prior
11.	Space and Missile Systems Organization U. S. Air Force Systems Command

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13. ABSTRACT

Laboratory tests were conducted on representative rock core specimens received from six core holes located in Clinton, Essex, Franklin, and Warren Counties near Plattsburgh Air Force Base, New York. The results of these tests were used to gage the quality and uniformity of the rock to depths of 200 feet below ground surface. The core was petrographically identified as predominately quartz sandstone and granite gneiss with relatively small amounts of amphibolite and mica schist. Schmidt hardness, specific gravities, compressional wave velocities, and ultimate uniaxial compressive strengths varied considerably throughout the area, depending primarily on rock type, bedding, and nature and degree of fracturing and/or banding present, if any. A hole-to-hole evaluation of the area, based on physical properties exhibited, indicates that the sandstone yielded by Holes P-CR-64 and P-CR-72 was generally competent rock, provided anisotropy is not a disqualifying quality. The granite gneisses tested from Holes P-CR-22 and P-CR-81 would also, in spite of the presence of some material of marginal quality, appear to be relatively competent rock. The gneiss received from Holes P-CR-8 and P-CR-46 contained significant amounts of incompetent material. More extensive investigations will be required in order to accurately assess the areas under consideration.

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Unclassified
Security Classification

038100
LB

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Plattsburgh area, N. Y.						
Rock cores						
Rock properties						
Rock tests						